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TRIDENT BIOLOGICAL SURVEYS: NAVAL SUBMARINE BASE BANGOR, WASHINGTON (1979, 1980 & 1981) SUMMARY REPORT (SUPPLEMENT 3 TO NUC TP 510)

J. G. Grovhoug

15 September 1982

Prepared for
Naval Submarine Base
Bangor, Washington

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NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

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JM PATTON, CAPT, USN
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HL BLOOD
Technical Director

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Marine biota adjacent to ~~SUBASE~~ Bangor were examined during 1979-1981 surveys. Marine fishes, intertidal molluscs and heavy metals in sediments and selected marine organism tissues were described. The effects of recent construction activities on the Hood Canal marine ecosystem were evaluated. Adverse impact has been limited to physical disruption of biota in the immediate vicinity of construction sites. Certain marine organisms have increased in population size as a result of habitat enhancement. Biotic fluctuations are in synchrony with adjacent areas in Puget Sound.

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OBJECTIVES

1. Document annual abundance and distribution of commercially and recreationally important marine biota adjacent to SUBASE Bangor.

2. Monitor heavy metal levels in sediments and selected organisms.

3. Provide data to assist SUBASE Bangor resource management planning.

4. Evaluate significant patterns in data collected and compare with previous SUBASE Bangor marine environmental survey findings.

5. Recommend future study needs.

RESULTS

1. Habitat for many fish species has increased since 1975.

2. Marine fish surveys documented diverse nearshore assemblages.

3. Otter trawl sampling for marine fishes was most efficient at night.

4. Feeding habits for selected fish species were described.

5. External parasitic infestation of certain flatfish species was observed.

6. Intertidal bivalve surveys documented the density and distribution of commercial species at seven locations along Hood Canal.

7. Maximum bivalve densities occurred at southern SUBASE Bangor stations.

8. Butter clams yielded the greatest biomass when compared with other intertidal molluscan biota.

9. Native littleneck clams were the most numerically abundant bivalve species.

10. Extensive oyster beds were observed and described along SUBASE Bangor waterfront areas.

11. Heavy metal surveys of selected sediments and tissues were performed in 1980 and 1981.

12. Heavy metal data reflect values similar to other Puget Sound regions.

13. Comparisons were made with earlier SUBASE Bangor marine survey data.

RECOMMENDATIONS

1. Continue to monitor nearshore marine environmental regions annually at SUBASE Bangor.

2. Retain marine fish surveys, intertidal surveys and heavy metal surveys during future monitoring investigations.

3. Develop detailed resource management plans for selected marine biota inhabiting SUBASE Bangor waterfront regions.

4. Document significant ecological events as they occur throughout the year to enhance annual survey perspectives and evaluations.

5. Encourage selected commercial and recreational utilization of intertidal bivalves and marine fishes along SUBASE Bangor.

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EXECUTIVE BRIEF

The marine environment at the Naval Submarine Base, Bangor, Washington was surveyed three times between July 1979 and July 1981 in a continuing effort to document environmental conditions along Navy-controlled shoreline areas adjacent to Hood Canal. The surveys provide baseline data for assessments of potential environmental responses to the newly-constructed Trident Submarine Support Facility. One goal of the surveys is to document the annual abundance and distribution of commercially and recreationally important species of marine biota. Another objective is to monitor levels of certain heavy metals in sediments and in selected marine organisms to provide a yearly measure of trace metal status within the marine community. A third objective is to provide Naval Submarine Base Bangor with meaningful marine environmental data to enhance resource management planning efforts. This summary presents results from refined field surveys made during the completion of major waterfront construction projects along Hood Canal. Only the more reliable, productive and cost-effective field sampling activities from previous surveys were retained during the surveys reported here.

Marine fish surveys indicated diverse and apparently healthy assemblages of ichthiofauna are present along SUBASE Bangor nearshore areas of Hood Canal. Habitat for many species has been greatly enhanced through the addition of waterfront structures. Marine fish collections during this three-year reporting period totaled more than 2000 specimens representing 37 species from 18 families of fishes. Feeding habit analyses for 17 selected species from 10 families documented 42 categories of diet items. Crustaceans, fishes, polychaete worms and bivalve molluscs were the predominant food items for fishes examined. These data indicate that the fish have diverse feeding patterns which are consistent with healthy, productive marine environmental conditions.

Intertidal surveys showed that commercially and recreationally important bivalve molluscs are abundant along SUBASE Bangor waterfront areas. These populations experience normal fluctuations in recruitment, growth and survival. Maximum densities of commercially important clams occur two feet on either side of tidal datum (MLLW) along SUBASE Bangor. Butter clams represented the highest biomass of important bivalves during this period. Native littleneck clams were the most numerically abundant commercial bivalve species. The densest populations of bivalves along SUBASE Bangor were in the southern sampling areas. Harvestable oyster beds now represent a significant resource along SUBASE Bangor.

Sediment and tissue heavy metal data are important aspects of continued environmental monitoring surveys at SUBASE Bangor. Several species of marine biota sampled at SUBASE Bangor concentrate certain heavy metals biologically. Heavy metal levels measured during 1980 and 1981 indicated levels in sediments and selected biota are similar at SUBASE Bangor stations to other regions of central and southern Puget Sound.

Annual environmental surveys provided consistent and reliable estimates of potential ecosystem response to construction activities during this reporting period. Data from these surveys indicate that the marine ecosystem along SUBASE Bangor shoreline has not been adversely changed by Trident construction activities. Biological fluctuations observed at

SUBASE Bangor are in natural synchrony with fluctuations elsewhere in Hood Canal and other Puget Sound regions. No rare or endangered species or critical marine habitat has been threatened by construction activities. Habitat has been effectively enhanced by the increased number of piers and wharfs along SUBASE Bangor. Adverse impact has been limited to the marine organisms physically disrupted by the mechanical process of pier construction.

INTRODUCTION

In 1973, the Naval Facilities Engineering Command requested that the Naval Ocean Systems Center (then designated the Naval Undersea Center) perform a series of biological surveys at the proposed Trident Submarine Support Facility located on Bangor Annex of the Keyport Naval Torpedo Station, Washington. This facility has been redesignated Naval Submarine Base Bangor (SUBASE Bangor). Four seasonal surveys were conducted to provide baseline biological data to assess the effects of construction on commercially and recreationally important populations of marine molluscs and fishes. Other marine biota which are important components of the Hood Canal ecosystem were sampled to determine their general condition, abundance and distribution in the study area. Also, a number of improved environmental monitoring techniques were developed and tested during these surveys. The first four surveys – Trident Surveys I-IV – were conducted in June and October 1973, and January and April-May 1974, respectively. A fifth survey was performed in July 1975 at the request of the officer-in-charge-of-construction for the Trident Facility (OICC Trident). The results of surveys I-V were documented in field data reports submitted to OICC Trident and in reference 1.

In July 1976, a sixth survey (VI) was conducted after waterfront construction began for the explosives-handling wharf (EHW) and piling stress testing near the planned Delta Complex site. This survey was designed to assess the effects of construction on marine life at SUBASE Bangor by comparing new data with those collected during surveys I-V. The results of survey VI were published in reference 2. This report contained an extensive cumulative checklist of marine flora and fauna recorded from Hood Canal during surveys I-VI.

In July 1977 and June 1978, surveys VII and VIII, respectively, were conducted to monitor and evaluate the effects of Trident construction activities on marine life along the SUBASE Bangor waterfront areas. The results of these surveys were analyzed and compared with the previous six surveys. A summary report of surveys VII and VIII was published (ref 3). Because most shoreline construction was completed before survey VIII, data from this survey provided a comparison to evaluate the impact of Trident construction activities on the marine life at SUBASE Bangor. The data from survey VIII were also used to evaluate field and analytical methods used during previous surveys to monitor the effects of shoreline construction on resident marine biota. This analysis supported several recommendations for improving the survey design and optimizing field collection efforts. Additionally, this evaluation recommended techniques for effectively monitoring the marine environment at SUBASE Bangor as it is upgraded into an operational Trident submarine training base and refit facility.

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[2] Naval Undersea Center TP 510 (Supplement 1), Trident Biological Survey: July 1976, by TJ Peeling, MH Salazar, JG Grovhoug and HW Goforth, 58p, 1976

[3] Naval Ocean Systems Center TR 513 (Supplement 2 to NUC TP 510), Trident Biological Surveys: SUBASE Bangor (July 1977 and June 1978) and Indian Island Annex (January, May 1974 and June 1978), HW Goforth, TJ Peeling, MH Salazar and JG Grovhoug, 84p, 1979

Beginning with survey IX in July 1979, several changes in survey design were effected. All sampling locations were critically evaluated in terms of relevant data contribution. Those sites which were not yielding useful and representative data were deleted. Some sites were repositioned and redesignated within the same general region. Intertidal delta regions containing major freshets at low tidal periods typically possessed bivalve concentrations much lower than areas which were qualitatively observable as high-density, productive clamming beaches. Station E, at Devil's Hole delta, is an example of this pattern. Because we observed dense clam aggregations on either side of the transect area for several years, in 1979 the intertidal sampling station was moved south about 150 metres and redesignated as station D. For the purposes of otter trawl sampling, this station is referred to as station D-E. To the north, the problem at station K was similar. Station K was deleted and a new station, designated J, was established about 200 metres north of the old station K. Otter trawl data were labeled J-K from this area. The new station J, however, was located nearer station L, the off-base northern control site, and thus a new problem was encountered. Station L had consistently yielded low-density data for intertidal bivalves and marine fishes. Therefore, in 1979, concurrent with the establishment of station J and based on previous recommendations (ref 3), station L was deleted from all further monitoring efforts. Further north, an off-base control station was selected and designated as station M. This station was sampled intensively during the 1979 survey, but because intertidal bivalve data at this site were not representative of a commercially important station, the utility of station M as an off-base control station was questionable. This station was deleted during 1980 and 1981 intertidal bivalve surveys. However, otter trawl sampling has been retained at station M because representative fish data continue to be collected from this site. The offbase southern control station (A) is considered to provide ample representative data for comparison with on-base stations.

Survey X, performed in June-July 1980, included further refinements in SUBASE Bangor monitoring survey strategies. Water, sediment and selected organism tissues were collected and analyzed for selected heavy metals. These data were to be part of a baseline for monitoring heavy metal conditions along Hood Canal. Results from initial heavy metal analyses suggested several modifications in monitoring survey design. The data on heavy metals in water had low variability and was generally uninformative; such low variability is expected from a healthy marine environment. Sediment heavy metal data from some sites such as Marginal Wharf and KB Pier had an expected range of values, including typical pier signatures. Future monitoring of sediment heavy metal data at selected waterfront areas was supported by these data. Heavy metal samples from tissues of rockfish, crabs and mussels yielded data typical for the region. These tissue samples are considered useful for future monitoring efforts at SUBASE Bangor.

Additionally, during survey X, nighttime otter trawl collections augmented daytime trawls to evaluate the effects of time of day on catch. These data indicate that species abundance and feeding information are more typical from nighttime hauls.

Survey XI, in May-June 1981, focused on three surveys: marine fish, intertidal and heavy metals. Marine fish and intertidal surveys continue to be central to SUBASE Bangor monitoring efforts. Nighttime otter trawls and intertidal bivalve transects along seven Hood Canal stations yielded representative data during the 1981 survey. The heavy metal survey design was modified for future surveys by deleting sea cucumber muscle tissue collections and adding oyster tissue samples from selected sites. Sediment samples were collected from all major waterfront areas which were initially sampled in 1980.

The 1981 monitoring survey occurred in late May and early June, during a low tide period. Results indicate a reduced abundance and lowered biomass for marine fishes and intertidal bivalves during the early summer of 1981. The reduced catch is chiefly attributable to the earlier sampling period in 1981. Many juveniles of important sampled species are not generally available for sampling until mid-June.

A global perspective of the Hood Canal study area is shown in figure 1. Contrary to the implication of its name, Hood Canal is not an artificial channel but a glacially-made inlet which forms the westernmost portion of Puget Sound on the Olympic Peninsula. The fjord extends from its northern connection with central Puget Sound basin southwesterly for about eighty kilometres. The southerly reaches of Hood Canal are narrower and shallower than the northern part. At SUBASE Bangor the canal is two kilometres wide and averages about 100 metres deep. Extreme tidal variation is about 4.5 metres and tidal currents range up to 2.5 knots along the study area. Thus, for safety, diving operations were synchronized closely with slack-water periods. Annual summertime surveys are conducted at lowest annual minus tides to enhance intertidal sampling efforts. Reference locations and sampling stations used during 1979, 1980 and 1981 monitoring surveys (as well as older stations now deleted, but discussed in the text) are shown in figure 2. Precise latitudes and longitudes for specific sampling sites at these stations are in appendix A. A chronological summary of major SUBASE Bangor construction activities during the period 1975-1981 is listed in table 1.

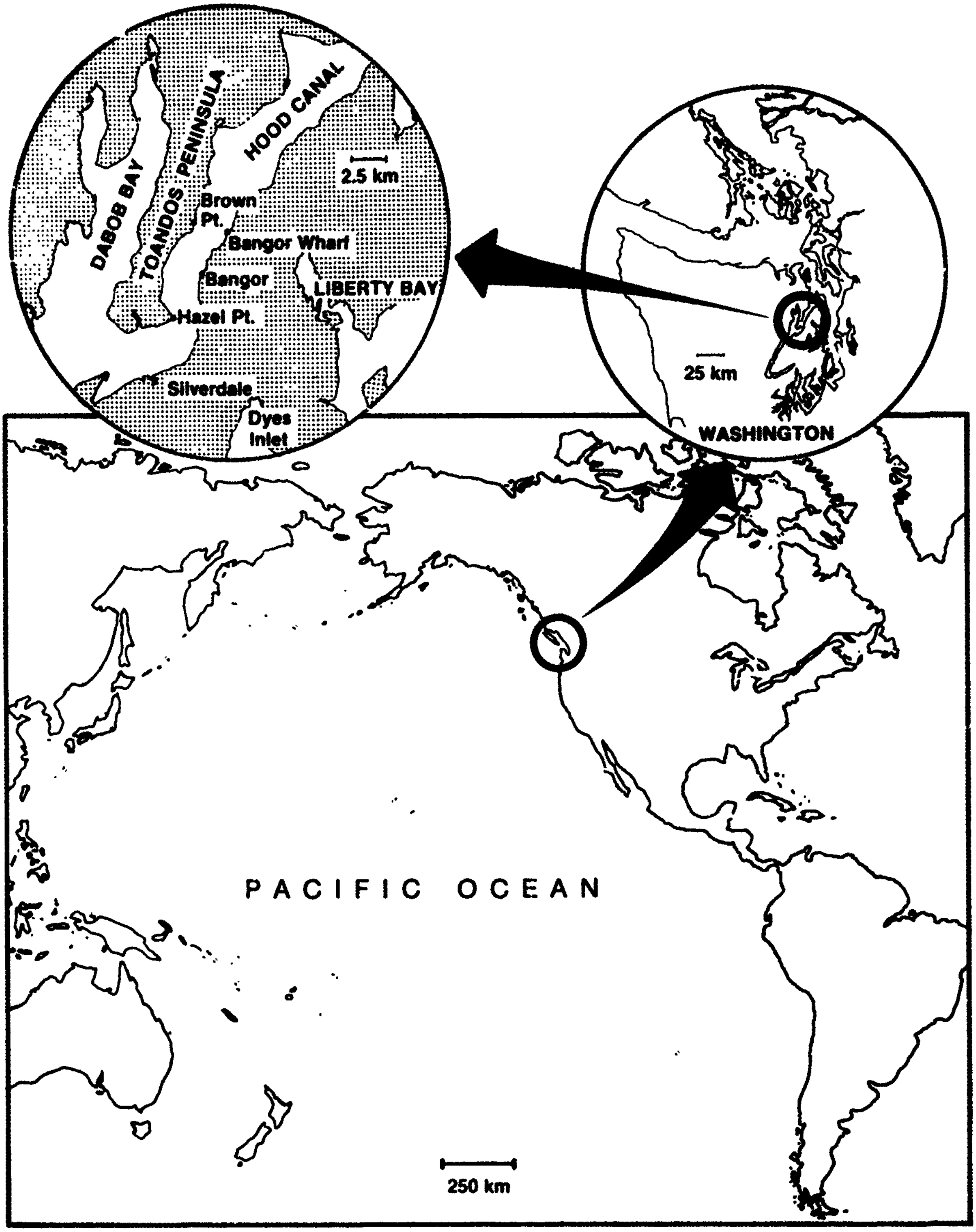

Figure 1. Hood Canal in perspective to the Pacific Basin.

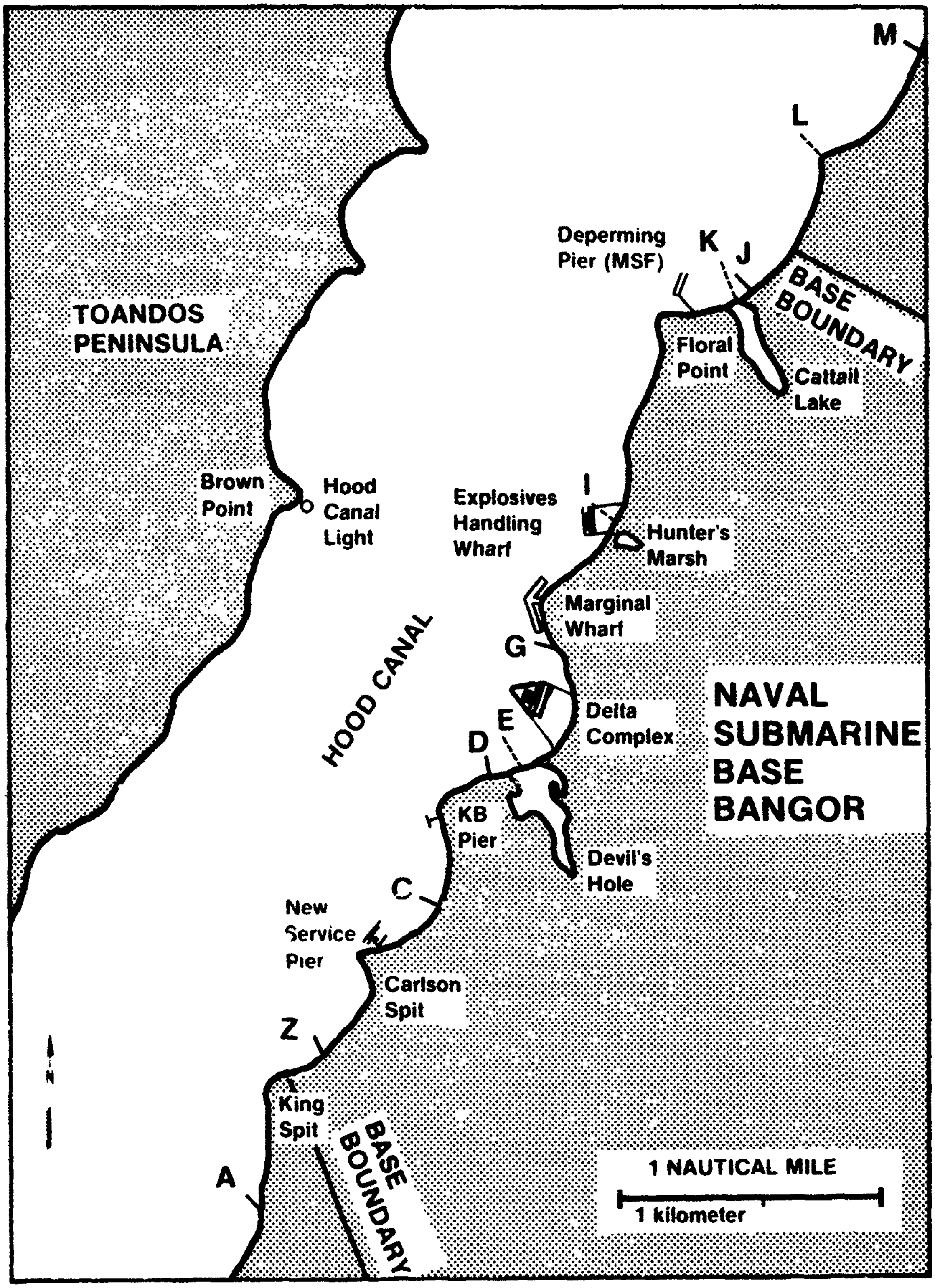

Figure 2. Sampling stations and points of reference along SUBASE Bangor waterfront areas.

Year	Waterfront Structure*	Construction Activity
1975	EHW	Began construction; test pile driving in June.
1976	DC	Preliminary pile driving; test wells drilled.
	EHW	Drove pilings and completed wharf area.
1977	DC	Completed pile driving and trestles; dredged entrance channel and drydock area; periodically pumped test wells; started drydock cofferdam construction.
	EHW	Completed wharf pilings and submarine berth enclosure; lighting partially operational in May.
	MSF	Commenced pile driving.
1978	DC	Completed drydock cofferdam and filling activities; drydock area dewatered; completed dredging within drydock.
	EHW	Completed lighting installation and began operational testing.
	MSF	Drove pilings, installed deck and partially completed lighting in June.
1979	DC	Completed drydock floor.
	MSF	Completed electrical installation; began operational testing.
	NSP	Began driving piles in June.
1980	DC	Completed construction of on-pier pilings; installed portal cranes; completed north trestle.
1981	DC	Drydock completed and operational.
	NSP	Pier completed and operational.

*DC = Delta Complex (including delta pier, drydock and trestles).
EHW = Explosives Handling Wharf.
MSF = Magnetic Silencing Facility (Deperming Pier).
NSP = New Service Pier.

Table 1. Summary of Trident construction activities at SUBASE Bangor during the period 1975-1981; refer to figure 2 for waterfront structure locations.

MARINE FISH SURVEYS

INTRODUCTION

Marine fishes inhabiting nearshore areas of Hood Canal are a conspicuous and valuable resource. Fishes are important components of the biotic community and have been sampled during each NOSC environmental monitoring survey at the Naval Submarine Base, Bangor. Dense aggregations of certain fish species such as seaperch, rockfish, greenlings, ling cod and herring inhabit waters adjacent to waterfront structures such as piers, pilings, buoys, docks and wharfs. Extensive subtidal eelgrass and laminarian beds along SUBASE Bangor offer prime habitat for many fishes such as copper rockfish, several species of flatfishes, seaperch, pipefishes and gobies. Juvenile salmonids (primarily pink and chum salmon outmigrants) feed in shoreline waters and use eelgrass beds as protection from predators (ref 4, 5). Adult salmonids generally remain in deeper-water areas of the canal during up-migration periods; however, mature chinook and coho salmon have been caught from wharf and pier areas along SUBASE Bangor (ref 6). Anadromous cutthroat trout and steelhead are seasonally abundant along waterfront areas.

The nearshore marine fish abundance and distribution along SUBASE Bangor were examined during summertime surveys in 1979, 1980 and 1981. The sampling effort was otter trawl collection along seven study areas in Hood Canal adjacent to SUBASE Bangor (figure 3). Previous studies (ref 7-9) plus our own experience at SUBASE Bangor indicate that nighttime trawls are more efficient for our purposes than daytime collections. Replicate trawls were conducted on separate nights to obtain representative data for analysis and comparison with previous surveys.

The species composition and abundance for each trawl was noted. Stomach contents of individual fish specimens were determined and parasitic infestation of certain flatfishes was noted. Results are presented later in this section. Where applicable, comparisons with previous survey data (ref 1-3) will be provided.

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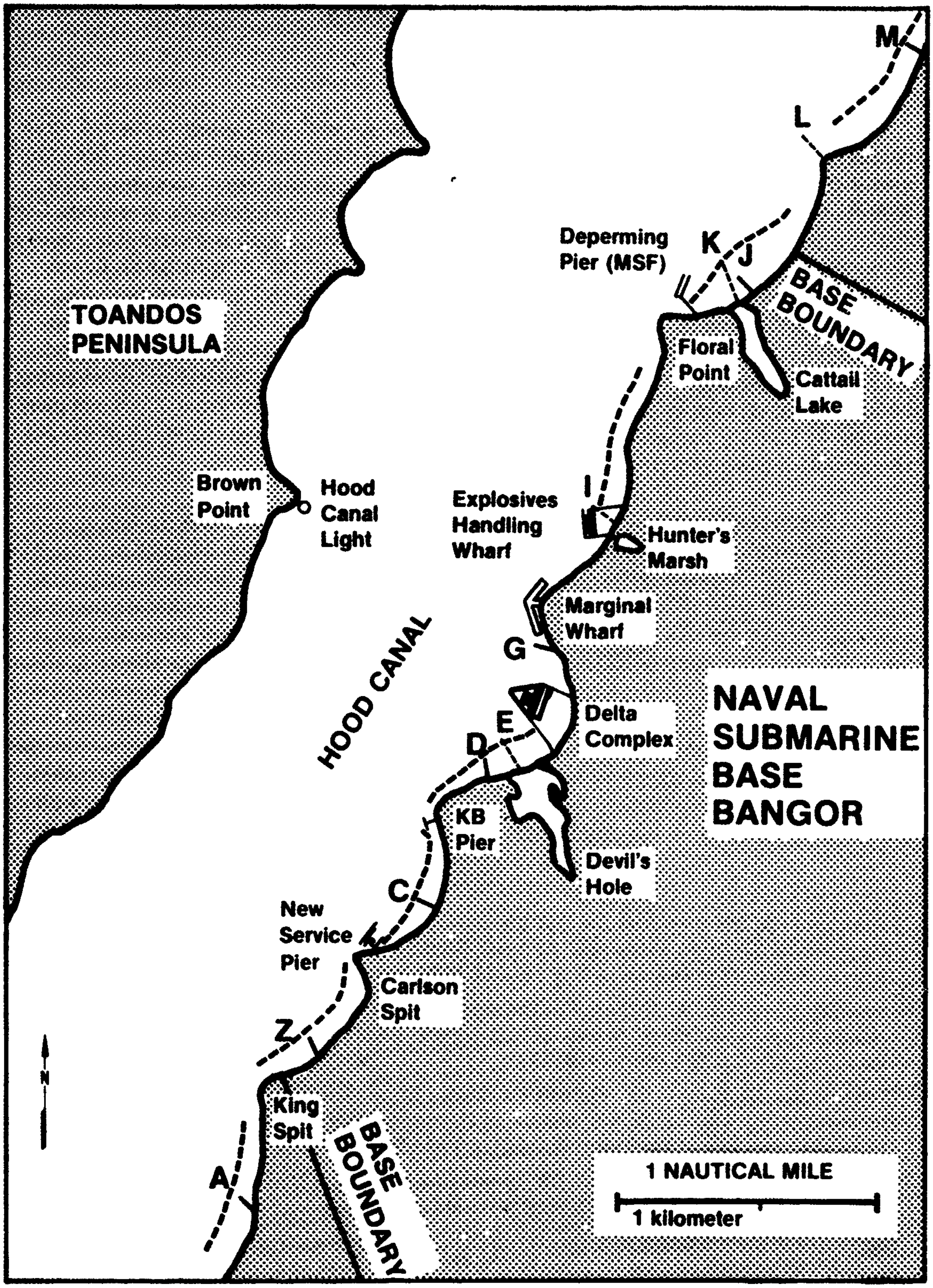

Figure 3. Otter trawl sampling locations adjacent to SUBASE Bangor.

MATERIALS AND METHODS

Replicate otter trawl samples were taken at stations A, C, D-E, I, J-K, M and Z (see figure 3 for locations) during summer nighttime hours in 1979, 1980 and 1981. The spread-board otter trawl had a 5-metre mouth opening, two 31.5 x 60cm boards weighing 8 kilograms each, a bag of 28-mm stretch mesh, and a cod end of 13-mm stretch mesh. Ten-minute hauls were made from a 16-foot outboard-powered boat at a speed of approximately 1 metre/second (2 knots). Each trawl haul sampled about 650 metres of bottom linearly. A boat-mounted fathometer was used to maintain the trawl at 5-8 metres. That depth range corresponds to the deep side of the eelgrass beds and the shallow edge of the laminarian zone at each station. Most trawling was done over sandy substratum.

After each trawl, fish were separated from invertebrates, algae, eelgrass, rocks and shell debris, placed in labeled zip-lock or mesh bags (depending upon size of fish specimens) and returned to the laboratory in an ice-filled cooler for analysis. Adult fishes were identified to species in the onsite laboratory using taxonomic references for the region (ref 10-12). An important distributional checklist for Hood Canal fishes is found in reference 13.

Fish were identified, separated into species groups, counted, measured and weighed. Length was taken to the nearest millimetre as either fork or total length, depending on the species. Weights were determined to the nearest gram. Fish were examined for sex, maturity, parasites or other abnormalities and pertinent data were recorded. The specimens' physical condition was indicated by fin erosion, tumors or presence of the parasitic nematode, *Philometra americana* Costa, 1846. Our previous surveys only observed these encysted parasites in adult rock sole, *Lepidopsetta bilineata* (Ayres, 1955) (ref 1-3). Copper rockfish, *Sebastes caurinus* Richardson, 1845, within the 150-250-mm size range were set aside for heavy metal sample dissections (muscle and liver tissue). Stomach and intestinal tract were analyzed for most fishes greater than 175 mm in length. The contents of stomachs and intestines were visually examined using a variable power (7-70X) binocular dissecting microscope. Identifiable prey organisms or other material were recorded for each specimen examined. Fishes or prey species which could not be positively identified on site were preserved in 10% formalin-seawater solution. These specimens were taken to NOSC and, if necessary, delivered to specialists for final identification. A representative reference collection of Hood Canal biota is maintained at the NOSC Sample Processing Center in Hawaii.

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RESULTS AND DISCUSSION

During 1979, 1980 and 1981 monitoring surveys, more than 2000 individual specimens representing 37 species from 18 families of fishes (see table 2) were collected by otter trawl sampling. The 10 most commonly sampled species (listed in decreasing order of numerical abundance) were: english sole (*Parophrys vetulus*), copper rockfish (*Sebastes caurinus*), shiner perch (*Cymatogaster aggregata*), striped seaperch (*Embiotoca lateralis*), rock sole (*Lepidopsetta bilineata*), padded sculpin (*Artedius fenestralis*), C-O sole (*Pleuronichthys coenosus*), plainfin midshipman (*Porichthys notatus*), Pacific tomcod (*Microgadus proximus*) and bay pipefish (*Syngnathus leptorhynchus*). Three other common species, tubesnouts (*Aulorhynchus flavidus*), three-spine sticklebacks (*Gasterosteus aculeatus*) and tadpole sculpins (*Psychrolutes paradoxus*) were recorded as too numerous to count (TNTC) during several sampling periods; therefore, exact numerical data are not available for these species (table 3).

Five new species of fishes were added to the Trident survey cumulative checklist during 1979 and 1980 field studies. These species were: *Porichthys notatus, Gadus macrocephalus, Artedius lateralis, Agonus acipenserinus* and *Citharichthys sordidus.* All of these species have been reported previously from Hood Canal (ref 13).

Survey data show that fish abundance and distribution fluctuated from survey to survey. Catches were large at most stations during 1979 and 1980 surveys. However, during the 1981 survey, fish abundance was markedly reduced. The 1981 survey was conducted earlier in the year (May-June) than previous annual surveys (late June-July), which may partially explain the observed reduction in fish abundance. Additionally, only a single trawl was taken at stations A, D-E, J-K and M during 1981. Divers' qualitative observations adjacent to underwater structures during 1979, 1980 and 1981 indicate an enhanced abundance for many species. Increased piling surfaces provide additional epifaunal habitat and concomitant increases in fish abundance around pier and wharf areas. Habitat enhancement for many species has occurred along SUBASE Bangor during the last five years, but many of these waterfront areas cannot be sampled with an otter trawl because of subsurface obstructions and underwater debris. Thus, the otter trawl catch data provide information on fish species inhabiting unobstructed shoreline areas, primarily eelgrass and laminarian habitats. Otter trawl sampling methods remained consistent during 1979, 1980 and 1981 monitoring surveys; results compare with previous surveys, even though fish collections during the 1973-1978 period were from daytime trawls only. Daily catch records for the 1979-1981 fish trawl collections are listed in appendix B.

The 1979 trawl samples took 1199 individual fishes representing 31 species from 16 families. The samples were from one daytime and two nighttime trawl series. The daytime trawls collected 217 individuals representing 13 species from 9 families. Nighttime trawls were more productive. Night trawl series data are summarized in table 3. Two trawls were taken at each station on two separate nights, approximately one week apart. Annual trawl data are given in table 4. During the 1980 survey, 840 individuals representing 30 species from 15 families were collected.

Family	Genus/Species/Authority/Date	Common Name
Squalidae	*Squalus acanthias* Linnaeus, 1758	Spiny Dogfish
Chimaeriidae	*Hydrolagus colliei* (Lay & Bennett, 1839)	Ratfish
Batrachoididae	*Porichthys notatus* Girard, 1854	Plainfin Midshipman
Gadidae	*Gadus macrocephalus* Tilesius 1810	Pacific Cod
	Merluccius productus (Ayres, 1855)	Pacific Hake
	Microgadus proximus (Girard, 1854)	Pacific Tomcod
Aulorhynchidae	*Aulorhynchus flavidus* Gill, 1861	Tubesnout
Gasterosteidae	*Gasterosteus aculeatus* Linnaeus, 1758	Threespine Stickleback
Syngnathidae	*Syngnathus leptorhynchus* Girard, 1854	Bay Pipefish
Embiotocidae	*Cymatogaster aggregata* Gibbons, 1854	Shiner Perch
	Embiotoca lateralis Agassiz, 1854	Striped Seaperch
	Rhacochilus vacca (Girard 1855)	Pile Perch
Stichaeidae	*Anoplarchus purpurescens* Gill, 1861	High Cockscomb
	Lumpeneus sagitta Willmovsky, 1956	(Pacific) Snake Prickleback
Pholidae	*Apodichthys flavidus* Girard, 1854	Penpoint Gunnel
	Pholis laeta (Cope, 1873)	Crescent Gunnel
	Pholis ornata (Girard, 1854)	Saddleback Gunnel
Ammodytidae	*Ammodytes hexapterus* Pallas, 1811	Pacific Sand Lance
Gobiidae	*Coryphopterus nicholsi* (Bean, 1881)	Blackeye Goby
Scorpaenidae	*Sebastes caurinus* Richardson, 1845	Copper Rockfish
Hexagrammidae	*Hexagrammos stelleri* Tilesius, 1809	Whitespotted Greenling
Cottidae	*Artedius fenestralis* Jordan & Gilbert, 1882	Padded Sculpin
	Artedius lateralis (Girard, 1854)	Smoothhead Sculpin
	Clinocottus acuticeps (Gilbert, 1895)	Sharpnose Sculpin
	Enophrys bison (Girard, 1854)	Buffalo Sculpin
	Hemilepidotus hemilepidotus (Tilesius, 1810)	Red Irish Lord
	Leptocottus armatus Girard, 1854	Pacific Staghorn Sculpin
	Nautichthys oculofasciatus (Girard, 1857)	Sailfin Sculpin
	Psychrolutes paradoxus Gunther, 1861	Tadpole Sculpin
	Scorpaenichthys marmoratus (Ayres, 1854)	Cabezon
Agonidae	*Agonus acipenserinus* Tilesius, 1811	Sturgeon Poacher
Bothidae	*Citharichthys sordidus* (Girard, 1854)	Pacific Sanddab
Pleuronectidae	*Lepidopsetta bilineata* (Ayres, 1855)	Rock Sole
	Parophyrs vetulus Girard, 1854	English Sole
	Platichthys stellatus (Pallas, 1811)	Starry Flounder
	Pleuronichthys coenosus Girard, 1854	C–O Sole
	Psettichthys melanostictus Girard, 1854	Sand Sole

Table 2. List of Hood Canal fishes collected during Trident environmental monitoring surveys (1979, 1980 and 1981). (Taxonomy based on Hart, 1973.)

Species	A			C			D-E			I			J-K			M			Z		
	'79	'80	'81*	'79	'80	'81	'79	'80	'81*	'79	'80	'81	'79	'80	'81*	'79	'80	'81*	'79	'80	'81
Squalus acanthias	1	–	–	–	–	–	–	–	–	–	–	–	–	2	1	1	1	–	–	–	–
Hydrolagus colliei	2	2	–	–	–	–	–	–	2	–	–	–	2	2	–	–	–	3	1	–	–
Porichthys notatus	33	5	–	–	–	–	–	–	–	–	–	–	5	4	–	–	–	–	–	–	–
Gadus macrocephalus	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
Merluccius productus	9	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
Microgadus proximus	–	1	–	–	–	–	–	–	–	5	3	–	19	12	2	15	2	–	–	–	–
Aulorhynchus flavidus	2	4	–	TNTC	–	–	4	1	–	3	1	–	TNTC	1	1	3	26	–	1	–	–
Gasterosteus aculeatus	TNTC	1	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
Syngnathus leptorhynchus	40	–	–	1	–	–	1	–	–	–	–	1	3	–	–	–	–	–	–	–	–
Cymatogaster aggregata	29	i	–	7	–	5	9	1	–	12	1	15	31	5	–	26	4	2	6	–	–
Embiotoca lateralis	69	3	–	4	–	–	5	–	–	4	2	8	3	–	–	7	–	–	1	–	–
Rhacochilus vacca	1	1	–	–	–	–	–	–	–	3	–	–	–	–	1	–	–	–	–	–	–
Anoplarchus purpurescens	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lumpeneus sagitta	–	–	–	–	–	–	–	–	–	–	–	–	1	5	–	5	14	–	–	–	–
Apodichthys flavidus	1	–	–	1	–	–	1	–	–	2	1	–	–	–	–	–	–	–	1	–	–
Pholis laeta	56	3	–	1	–	–	–	–	–	1	1	–	–	–	–	–	–	–	3	–	–
Pholis ornata	7	–	–	–	–	–	–	1	–	–	1	2	3	–	–	–	–	–	–	1	–
Ammodytes hexapterus	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
Coryphopterus nicholsi	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Sebastes caurinus	179	49	11	18	14	4	12	5	9	8	23	4	18	8	2	–	2	–	27	26	4
Hexagrammos stelleri	2	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Artedius fenestralis	35	–	–	1	–	–	5	–	–	–	–	2	7	13	–	1	–	1	2	–	–
Artedius lateralis	–	1	–	–	–	–	–	–	–	–	1	–	1	2	–	–	3	–	–	–	–
Clinocottus acuticeps	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–
Enophrys bison	19	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
Hemilepidotus hemilepidotus	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Leptocottus armatus	14	2	–	2	–	–	3	–	–	2	–	1	4	–	1	2	–	–	1	–	–
Nautichthys oculofasciatus	1	1	–	–	1	–	–	–	–	3	5	–	1	2	–	1	–	–	–	–	–
Psychrolutes paradoxus	–	–	–	–	–	–	–	5	–	–	TNTC	–	TNTC	TNTC	–	2	29	–	–	–	–
Scorpaenichthys marmoratus	2	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	–
Agonus acipenserinus	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
Citharichthys sordidus	–	–	–	–	2	–	–	3	–	–	–	–	1	7	–	1	23	3	–	–	–
Lepidopsetta bilineata	–	30	1	–	–	1	–	–	–	1	–	–	1	12	–	1	45	8	–	2	1
Parophrys vetulus	7	8	–	3	3	3	4	2	–	–	6	1	42	12	–	47	322	14	–	2	2
Platichthys stellatus	15	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
Pleuronichthys coenosus	9	10	–	–	–	–	–	–	–	–	1	–	2	7	1	–	–	–	–	–	–
Psettichthys melanostictus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18	–	–	–	–

*single trawl data.
TNTC = Too numerous To Count

Table 3. Summarized otter trawl data (1979, 1980 and 1981).

	1979			1980			1981				
Station	1		2	1		2	1		2	Mean/ Station	%
A	171	(24)	363	41	(17)	83	14	(4)	–	134.4	35
C	33	(11)	7	9	(5)	385	5	(4)	8	12.3	4
D-E	21	(10)	24	12	(7)	6	11	(2)	–	14.8	4
I	17	(14)	30	25	(13)	30	0	(9)	35	22.8	7
J-K	66	(21)	85	31	(18	65	9	(7)	–	51.2	13
M	56	(13)	55	109	(14)	385	31	(6)	–	127.2	33
Z	19	(11)	26	16	(5)	16	1	(3)	6	14.0	6
Totals =	383		590	243		597	71		49	1933+	100
Means:		486.50			420.00			60.00			

Table 4. Data summary for nighttime otter trawls conducted at SUBASE Bangor during 1979, 1980, and 1981. Numbers of individuals listed for each of two trawling periods; number of species (in parentheses) combined year totals.

Certain stations consistently provided greater catches: A, M, J-K and I, provided 35%, 33%, 13% and 7% of the three-year combined mean trawl catch, respectively. These four stations account for 88% of the total catch during the three-year period. Each of these stations possesses a well-developed eelgrass and laminarian zone habitat.

Eight fish species were ubiquitous, ie collected at each otter trawl sampling station, during the 1979-1981 survey period. These species are *Aulorhynchus flavidus, Cymatogaster aggregata, Embiotoca lateralis, Sebastes caurinus, Artedius fenestralis, Leptocottus armatus, Lepidopsetta bilineata* and *Parophrys vetulus*. These species are typical of Hood Canal and represent a healthy nearshore marine environment.

Flatfishes collected along SUBASE Bangor are typically infested by the parasitic dracunculid nematode, *Philometra americana*. Table 5 summarizes rock sole, *Lepidopsetta bilineata*, infestation data from the 1979-1981 surveys. During previous studies (ref 1-3) *Philometra* occurrence was only observed on adult (> 250-mm) rock sole. During 1979, 1980 and 1981 surveys, 8% of individuals less than 250 mm were infested. Fifty percent of adult rock sole contained *Philometra* cysts during these surveys. Four other flatfish species taken in the 1979-1981 surveys contained *Philometra* cysts. These species are: english sole, *Parophrys vetulus*, starry flounder, *Platichthys stellatus*, C-O sole, *Pleuronichthys coenosus*, and sand sole, *Psettichthys melanostictus*. These data are consistent with those reported for other Puget Sound locations (ref 14). When compared with the rock sole data, *Philometra* infestation has been observed on both juvenile and adult sized individuals for these other flatfish species. However, *Philometra* occurrence was observed only on C-O soles greater than 250 mm in length. These data are listed in table 6. Except for sand sole, *Philometra* occurrence is reduced for three flatfish species other than rock sole. All sand sole collected were infested with *Philometra* cysts.

Feeding Habits

Food habits were analyzed for fish longer than 175 mm collected in otter trawl samples during 1979 and 1981 surveys. During the 1980 survey, however, only copper rockfish specimens (which were also used for heavy metal tissue analyses) were analyzed because trawl catches were so large. For the three-year period, the stomach, esophageal and intestinal regions of 140 individuals, representing 17 species from 10 families of fishes, were examined. Contents of intestines were often only partially recognizable. Hard items such as juvenile bivalve molluscs, fish skeletal remains and crustacean exoskeletons were identifiable from the intestines. These data provide information on the feeding habits of certain Hood Canal fish species. Forty-two categories of diet items are listed in table 7. All species examined demonstrated carnivorous feeding habits. Additionally, many species ingested plant materials. However, marine plants (algae and *Zostera*) comprised a small percentage of total gut contents. Ingestion of plant materials is probably incidental to the primary animal diet items in these species.

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14 Wingert, RC, McCain, BB, Pierce, KV, Borton, SF, Griggs, DT, and Miller, GS, Ecological and Disease Studies of Demersal Fishes in the Vicinity of Sewage Outfalls, College of Fisheries, University of Washington Contr 444, p 29-30, 1976

Survey	>250mm	# Infested	%	<250mm	# Infested	%
1979 (X)	1	1	100	3	1	33
1980 (X)	17	9	53	36	2	6
1981 (XI)	2	0	0	9	1	11
Totals	20	10		48	4	

Table 5. Rock sole infestation by *Philometra americana.*

Species	Survey	>250mm	# Infested	%	<250mm	# Infested	%
English Sole	1979 (IX)	19	1	5	96	5	5
	1980 (X)	9	2	11	349	5	1
C-O Sole	1980 (X)	5	2	40	13	0	0
Starry Flounder	1979 (IX)	15	2	7	2	2	100
Sand Sole	1980 (X)	9	9	100	6	6	100

Table 6. Flatfish other than rock sole infested by *Philometra americana.*

Taxa (Genus & species) / Number of specimens examined (in parentheses)	Mean length of specimens (mm)	Sex (♂ ♀ unknown)	Fishes (misc. fragements)	Chum salmon (*O. nerka*)	Herring (*Clupea harengus pallasi*)	Shiner seaperch (*C. aggregata*)	Flatfish (unidentified)	Tubesnout (*A. flavidus*)	Prickleback (Stichaeidae)	Gunnel (Pholidae)	Cabezon Eggs (*S. marmoratus*)	Marine Worms (Polychaeta)	Anemones (Cnidaria)	Comb Jellies (Ctenophora)	Mollusks (misc fragments)	Bivalves (misc. fragments)	Basket cockle (*C. nuttalli*)	Butter clam (*S. giganteus*)	*Cryptomya californica*	Jackknife clam (*S sicarius*)	*Macoma* sp	Tellen clam (*Tellina* sp.)	Clam Siphon Tips (misc)	Gastropods (misc. fragments)
Apodichthys flavidus (1)	265	0 0 1																						
Embiotoca lateralis (2)	254	0 1 1																						
Enophrys bison (1)	246	1.0:0	•																					
Hexagrammos stelleri (4)	289	0.4.0									•				•	•								•
Hydrolagus colliei (9)	562	1 8:0	•																					
Lepidopsetta bilineata (7)	269	2.5 0										•					●	•	•				●	
Leptocottus armatus (6)	221	2 3·1	•			●							•											
Lumpenus sagitta (1)	262	0·17·0																						
Merluccius productus (10)	317	0·10·0		•	●																			
Microgadus proximus (4)	201	0.2·0										•												
Nautichthys oculofasciatus (1)	168	0 0 1																						
Parophrys vetulus (26)	259	3 8 15										●					•	•	•		•	•	●	•
Platichthys stellatus ([illegible])	294	3·3:1										•					•						●	
Pleuronichthys coenosus (2)	265	0:0.2										●												
Scorpaenichthys marmoratus (4)	442	2.2·0								•	•													
Sebastes caurinus (52)	225	28 20.4	•		•	•		•	•			•								•				
Squalus acanthias (3)	624	1.2.0	•											●										

Taxa (Genus & species)	Nudibranchs (misc.)	Crustaceans (misc. fragments)	Barnacles (*Balanus* spp)	Shrimp (*Pandalus danae*)	Shrimp (misc fragments)	Skeleton Shrimp (Caprellidae)	Amphipods (Gammaridae)	Isopods	Crabs (misc fragments)	*Cancer magister*	*Cancer productus*	*Pugettia producta*	*Telmessus cheiragonus*	*Hemigrapsus nudus*	Brittle Stars (Ophiuroids)	Marine Plants (misc fragments)	Eel grass (*Zostera marina*)	Sea lettuce (*Ulva* sp)	Pea Gravel & Stones	Shell Debris	Empty Stomachs
Apodichthys flavidus (1)					•				•												
Embiotoca lateralis (2)		•														•				•	
Enophrys bison (1)																					
Hexagrammos stelleri (4)	•			●	•	•										•	•		•	•	
Hydrolagus colliei (9)		•	•	•					●		•					•				•	•
Lepidopsetta bilineata (7)																					•
Leptocottus armatus (6)				●	•				●		•						•		•		
Lumpenus sagitta (1)		•				•	•									•					
Merluccius productus (10)																					
Microgadus proximus (4)				•	•	●	•														
Nautichthys oculofasciatus (1)				•												•					
Parophrys vetulus (26)		•	•	•			•								•	•		•	•	•	•
Platichthys stellatus ([illegible])									•							•	•	•		•	•
Pleuronichthys coenosus (2)																					
Scorpaenichthys marmoratus (4)		•								•	●	●					•	•			
Sebastes caurinus (52)				●	•	•	•	•	•	•	•	•	•	•		•					•
Squalus acanthias (3)		•		•													•				

Table 7. Diet categories for selected fishes collected adjacent to SUBASE Bangor in Hood Canal during 1979, 1980 and 1981 surveys.

Table 7 summarizes the results of the food habit analyses. The larger dots represent major food items observed in more than 50% of specimens of a given species; small dots indicate less frequently consumed items. Feeding habits for many of the species listed in table 7 have been reported previously (ref 1-3). The feeding habits of fishes examined during 1979-1981 surveys are in general agreement with data from previous SUBASE Bangor surveys (1973-1978). Food habit analysis shows ecosystem complexity and interdependence of biotic relationships within the food webs of nearshore marine biota along SUBASE Bangor. Crustaceans were the principal diet items in fish guts analyzed during these surveys. Other major groups of diet items include: fishes, polychaete worms and bivalve molluscs.

Copper Rockfish (*Sebastes caurinus*)

Copper rockfish guts typically contained crustaceans, especially the shrimp, *Pandalus danae*, and other fishes. *Sebastes caurinus* is a faculative feeder which consumes a wide variety of food items present in the nearshore eelgrass beds and piling habitats along Hood Canal. Reference 15 describes similar feeding trends by copper rockfish from southern Puget Sound. Twenty food item categories were found in the guts of this species. Reference 16 examined food habits of *Sebastes caurinus* in southern Humboldt Bay, northern California and categorized copper rockfish as opportunistic carnivores. Our Hood Canal data support this description. Copper rockfish feed most actively at night and early morning hours (ref 15; observations during this study).

English Sole (*Parophrys vetulus*)

English sole consumed clam siphon tips and polychaete worms as major diet items. However, many other types of food items were identified from stomach and intestine analyses. English sole was the most frequently collected species during this survey period. We collected 480 individuals, mostly juveniles, ie < 100 mm. English sole apparently feed at night. English sole is the only species we sampled that fed on ophiuroids (brittle stars). During previous surveys (1973-1978) rock sole was the only species which contained ophiuroids.

Pacific Hake (*Merluccius productus*)

Pacific hake stomachs contained herring and, in one instance, juvenile chum salmon. These diet items were found in the stomachs of 10 specimens collected during the 1979 survey. Hake are nocturnal feeders, based upon observations made during this study and those reported elsewhere (ref 10).

Ratfish (*Hydrolagus colliei*)

Ratfish exhibited a preference for crabs as diet items; however, several specimens examined contained fish remains, barnacles, shrimp, marine plants and shell debris. These

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[15] Patten, BJ, Biological Information on Copper Rockfish in Puget Sound, Washington, Trans Am Fisheries Society, vol 102, p 412-416, 1973

[16] Prince, ED, Food of the Copper Rockfish, *Sebastes caurinus* Richardson, Associated with an Artificial Reef in South Humboldt Bay, California, California Fish and Game, vol 62, p 274-285, 1976

nocturnal predators were often collected in pairs, although eight out of nine specimens collected were females.

Rock Sole (*Lepidopsetta bilineata*)

Rock sole fed primarily on molluscs. Major diet items consisted of bivalve siphon tips and juvenile basket cockles. Polychaete worms were less frequent in rock sole stomachs. Reference 17 lists polychaetes and sandlances as principal diet items for rock sole in Hecate Strait, north of Vancouver Island, British Columbia.

Starry Flounder (*Platichthys stellatus*)

Starry flounder ingested clam siphon tips as a major diet item. This concurs with food habits for this species reported from Elkhorn Slough, California (ref 18). Polychaetes, small basket cockles and crab fragments were also identified from stomachs and intestines. This species of flatfish contains both right- and left-handed individuals. It is interesting that most males were observed to be right-handed in Hood Canal collections during this survey period.

Pacific Staghorn Sculpin (*Leptocottus armatus*)

Pacific staghorn sculpin are voracious feeders (ref 10). Shiner seaperch, shrimp and crabs were major diet items for this species. Anemones were also common in stomachs. Other fishes, eelgrass and pea gravel occurred less frequently in *Leptocottus armatus* feeding habits.

Whitespotted Greenling (*Hexagrammos stelleri*)

Whitespotted greenling fed primarily on the shrimp, *Pandalus danae*; however, many other diet items were identified from four female specimens examined during this period. *Hexagrammos stelleri* were collected from unobstructed eelgrass and laminarian zone habitats at stations A, D-E and I during the 1979 survey.

Pacific Tomcod (*Microgadus proximus*)

Pacific tomcod were common in otter trawl samples from the northern sampling stations I, J-K and M. Only four individuals larger than 175 mm were examined for food habit analysis during 1979, 1980 and 1981 surveys. The primary diet item for this species consisted of skeleton shrimp. Also polychaetes, shrimp and amphipods were ingested to a lesser extent. Little is known about the life history of this species in Puget Sound (ref 10).

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[17] Forrester, CR, and Thompson, JA, Population Studies on the Rock Sole (*Lepidopsetta bilineata*) of Northern Hecate Strait, British Columbia, Fisheries Research Board of Canada Tech Report 108, 104p, 1969

[18] Orcutt, HG, The Life History of the Starry Flounder, California Dep[illegible]n and Game Fish Bulletin 78, 64p, 1950

Cabezon (*Scorpaenichthys marmoratus*)

Cabezon fed chiefly on the red rock crab, *Cancer productus*. Specimens examined during this period also contained gunnels, cabezon eggs, miscellaneous crustacean fragments and marine plant debris. Cabezon were only collected from the two southernmost stations, A and Z.

Spiny Dogfish (*Squalus acanthias*)

Spiny dogfish sharks consumed ctenophores, fishes and shrimp. Seldom collected in otter trawls, this active carnivore was mainly present in trawls from northern stations along SUBASE Bangor. Reference 19 reported that in British Columbia waters, principally in the Strait of Georgia, spiny dogfish feed on Pacific herring, euphausids, unidentified eggs and caridean crustaceans during all combined life stages.

The remaining six species were represented by only one or two specimens for examination. Therefore, general comments regarding food habits during this survey period are not provided for these fishes. An excellent synthesis and summary of available knowledge concerning food web relationships of northern Puget Sound and the Strait of Juan de Fuca can be found in reference 5.

CONCLUSIONS

1. Fish abundance and distribution data collected during 1979, 1980 and 1981 surveys indicate that ichthiofauna along SUBASE Bangor are typically diverse and demonstrate characteristically healthy assemblages.

2. Increased nearshore habitat resulting from additional waterfront structures along Hood Canal at SUBASE Bangor supports numerically enhanced assemblages of many marine fish species.

3. Nighttime otter trawl collections provide a quantitative, reliable and cost-effective means to monitor marine fish fauna along SUBASE Bangor on an annual basis.

4. *Philometra americana*, a parasitic nematode, infested five common flatfish species inhabiting nearshore environments adjacent to SUBASE Bangor.

5. Diverse feeding habits were recorded for 17 common Hood Canal fish species. Crustaceans, fishes, polychaete worms and bivalve molluscs were predominant food items for fishes examined during this period.

6. The distribution and composition of marine fish assemblages at SUBASE Bangor have not shown adverse characteristics attributable to construction effects during the period 1979-1981.

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[19] Jones, BC, and Geen, GH, Food and Feeding Habits of Spiny Dogfish (*Squalus acanthias*) in British Columbia Waters, Journal Fisheries Research Board of Canada, vol 34, p 2067-2078, 1977

INTERTIDAL SURVEYS

INTRODUCTION

Regions of tidal influence are important components of most marine ecosystems. Nearshore intertidal regions: 1) provide nursery areas, food and habitat for many species of vertebrates and invertebrates; 2) are primary sites for nutrient cycling; 3) offer maximum available sunlight for photosynthetic activity; and 4) often support dense aggregations of economically important species of marine flora and fauna in a location that makes them available for human consumption. These regions of diverse, interdependent biotic assemblages are also susceptible to man-induced impacts such as resource removal (harvesting), habitat alteration and pollutant stresses. Intertidal environmental monitoring is warranted by economic, recreational and aesthetic values. These potentially impacted regions are ecologically important to the entire marine ecosystem.

Shoreline intertidal regions in Puget Sound are highly productive zones. At the SUBASE Bangor study area located along northern Hood Canal (see figure 2), certain intertidal transect sampling stations have been monitored annually since 1973 (ref 1-3). Central to monitoring efforts have been annual evaluations of recreationally, commercially and ecologically important species of marine bivalve molluscs, especially clams, oysters and mussels.

Bivalve Molluscs

Bivalve molluscs are sedentary or sessile, filter-feeding organisms which remain in a specific localized intertidal area. They dominate the biomass of intertidal regions in Puget Sound. These important marine organisms respond to environmental conditions present in a given locale. Their usefulness in monitoring studies is determined by measurable, albeit often subtle, responsiveness to environmental perturbations. The recreational and commercial importance of certain bivalve molluscs in Puget Sound is well established (ref 20-24).

This section presents distribution and density data for the following species of bivalves along SUBASE Bangor: *Saxidomus giganteus* (Deshayes, 1839), butter clam;

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[20] Amos, MH, Commercial Clams of the North American Pacific Coast, Bureau of Commercial Fisheries Circular 237, 18p, 1966

[21] Chew, KK, Prospects for Successful Manila Clam Seeding, College of Fisheries, University of Washington Contr 440, 13p, 1975

[22] Magoon, C, and Vining, R. Introduction to Shellfish Aquaculture in the Puget Sound Region, Division of Marine Land Management, Washington Dept of Natural Resources, 68p, 1981

[23] Quayle, DB, Distribution of Introduced Marine Mollusca in British Columbia Waters, Journal Fisheries Research Board of Canada, vol 21, p 1155-1181, 1964

[24] Westley, RE, The Oyster Producing Potential of Puget Sound, Proc. National Shellfisheries Assoc, vol 61, p 20-23, 1971

Protothaca staminea (Conrad, 1837), native littleneck clam; *Tapes* japonica* Deshayes, 1853, Japanese or Manila littleneck clam; *Clinocardium nuttallii* (Conrad, 1837), basket cockle; *Mya arenaria* Linnaeus, 1758, eastern softshell clam; *Tresus capax* (Gould, 1850) and *Tresus nuttallii* (Conrad, 1837), horseneck or gaper clams; *Panopea generosa* (Gould, 1850), geoduck clam; *Crassostrea gigas* (Thunberg, 1795), giant Pacific or Japanese oyster and *Mytilus edulis* Linnaeus, 1758, bay mussel. Figure 4 depicts the typical horizontal and vertical distribution and range of these species of bivalve molluscs along SUBASE Bangor. Geoduck and horseneck clams primarily occur subtidally throughout Puget Sound. These species are included in this section because they have been observed and collected during intertidal sampling along SUBASE Bangor shorelines. Subtidal distributional data for these species were reported previously (ref 1,2). Many other species of bivalve molluscs were collected during field surveys; however, due to their small size or undesirability as a source of food, these species are not considered recreationally or commercially important. Ecologically, many of these species are significant to functional aspects of the Hood Canal marine ecosystem.

MATERIALS AND METHODS

Intertidal transect sampling was performed at stations A, Z, C, D, G and J during 1979, 1980 and 1981 surveys. Additionally, station M, off-base to the north, was sampled only during 1979. As discussed previously, data from this station were not considered representative for the area, and, therefore, station M was deleted as an intertidal sampling station in 1980. The locations of NOSC intertidal transect stations at SUBASE Bangor are shown in figure 2; latitude and longitude data for each station are listed in appendix A.

Upon arrival at an intertidal transect station, usually about two hours prior to low tide, the survey team initially positioned sampling equipment on the beach, located the permanent high tidal level marker and deployed the transect line on a predetermined magnetic heading. Intertidal station sampling parameters are listed in table 8. A handheld magnetic bearing compass (figure 5) was used to position the intertidal transect line along the same axis for year to year comparisons of data. Two replicate digs were made along either side of the transect line at predetermined marks. The PVC-coated fiberglass transect line is marked in metres and decimetre gradations. Most transects were deployed perpendicular to the shoreline across the intertidal region from extreme high tidal mark to low tide level during each day of intertidal sampling. Using the computed time of low tide** and noting the distance along the transect line as a reference point, tidal heights were determined using a beach profiling technique (ref 26) described in detail previously (ref 3). The selection of distances

**Tapes japonica* (Deshayes, 1853) has been referred to by junior synonyms of *T. semidecussata* and *T. philipinarum* and variously placed in *Paphia, Venerupis, Protothaca* and *Ruditapes*, now used as a subgenus (ref 25)

**NOSC monitoring surveys were scheduled to coincide with the lowest tides during the sampling month, as listed in NOAA Tide Tables for the year.

[25] Smith, RI, and Carlton, JT, Light's Manual: Intertidal Invertebrates of the Central California Coast, 3d ed. p 562, University of California Press, 1975

[26] Emery, KO, A Simple Method of Measuring Beach Profiles, Limnology and Oceanography, vol 6, p 90-93, 1966

Station Designation	Magnetic Axis	Approx. Length(m)*	Major F/S Zones**	# Digs	Distance along line (m) & F/S Zones***
A	250°/070°	42	3	8	26, 29, 33, 36 B2, B2, C3, F6
Z	305°/125°	46	3	8	19, 23, 27, 35 AB2, B3, B3, C4
C	270°/090°	37	4	8	21, 26, 31, 35 AB3, B3, D3, E5
D	322°/142°	165	4	10	30, 50, 75, 100, 140 A3, B3, D4, D4, F5
G	310°/130°	35	3	8	18, 22, 28, 32 C3, C4, F6, F5
J	290°/110°	85	4	10	19, 25, 30, 40, 75 B2, B3, B5, D5, F5
M	260°/080°	75	4	8	20, 24, 46, 65 AB2, C5, D4, F5

*each transect extends from high water level to mean lowest tidal conditions; lengths and distances in metres.

**Faunal/substrate (F/S) zones (see below):

Faunal Zones	Substrate Zones
A–mussel/barnacle	1–riprap
B–oyster	2–boulders/rocks
C–shell debris	3–stones/gravel
D–ulvoids	4–pea gravel/sand
E–sargassum/laminoids	5–sand
F–eelgrass	6–mud/sand

***Zero end of transect line is at high tide marker.

Table 8. SUBASE Bangor intertidal station transect parameters during 1979, 1980 and 1981 surveys.

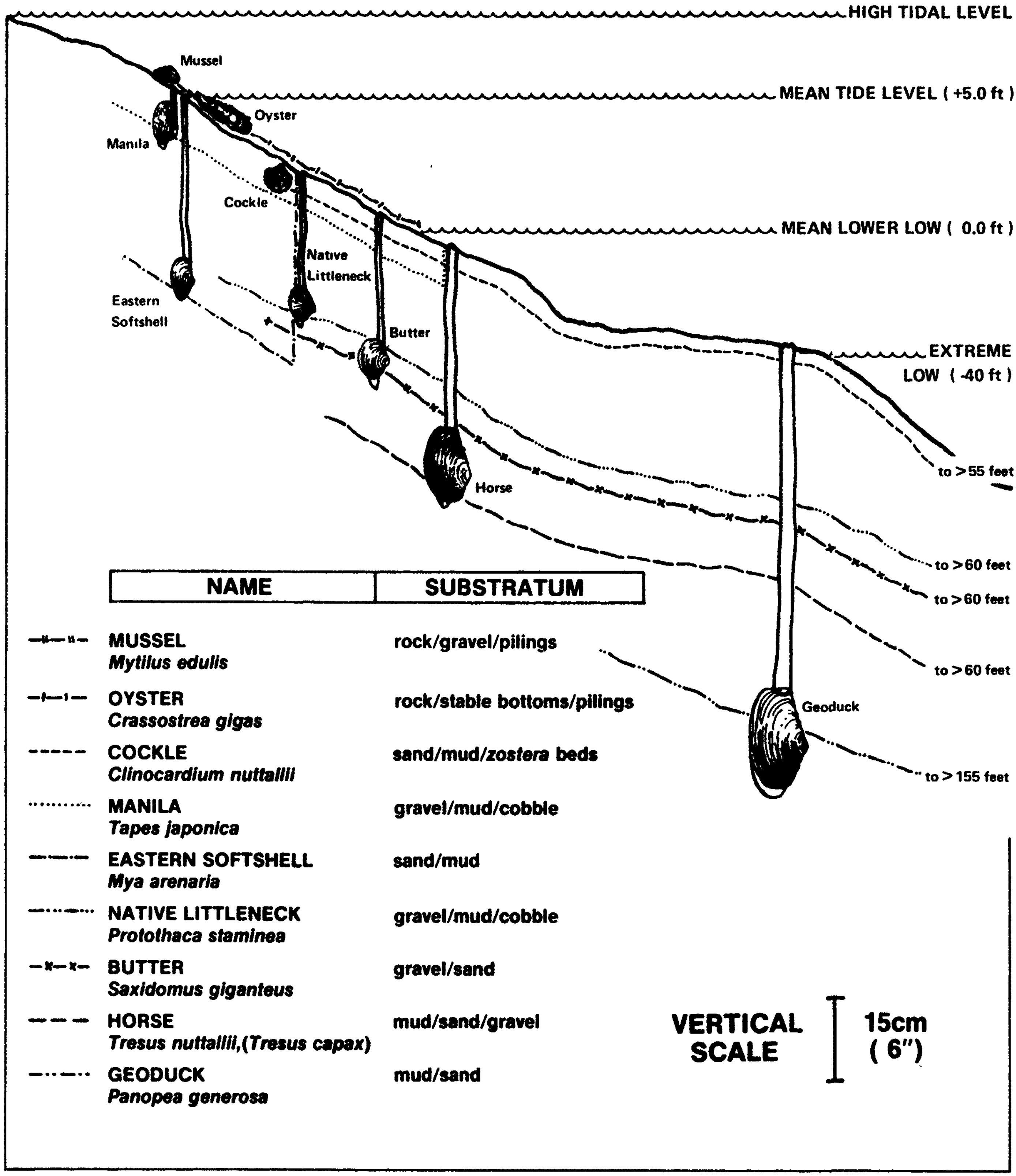

Figure 4. Horizontal and vertical distribution of major species of bivalve molluscs along SUBASE Bangor. (adapted from Ref. 22).

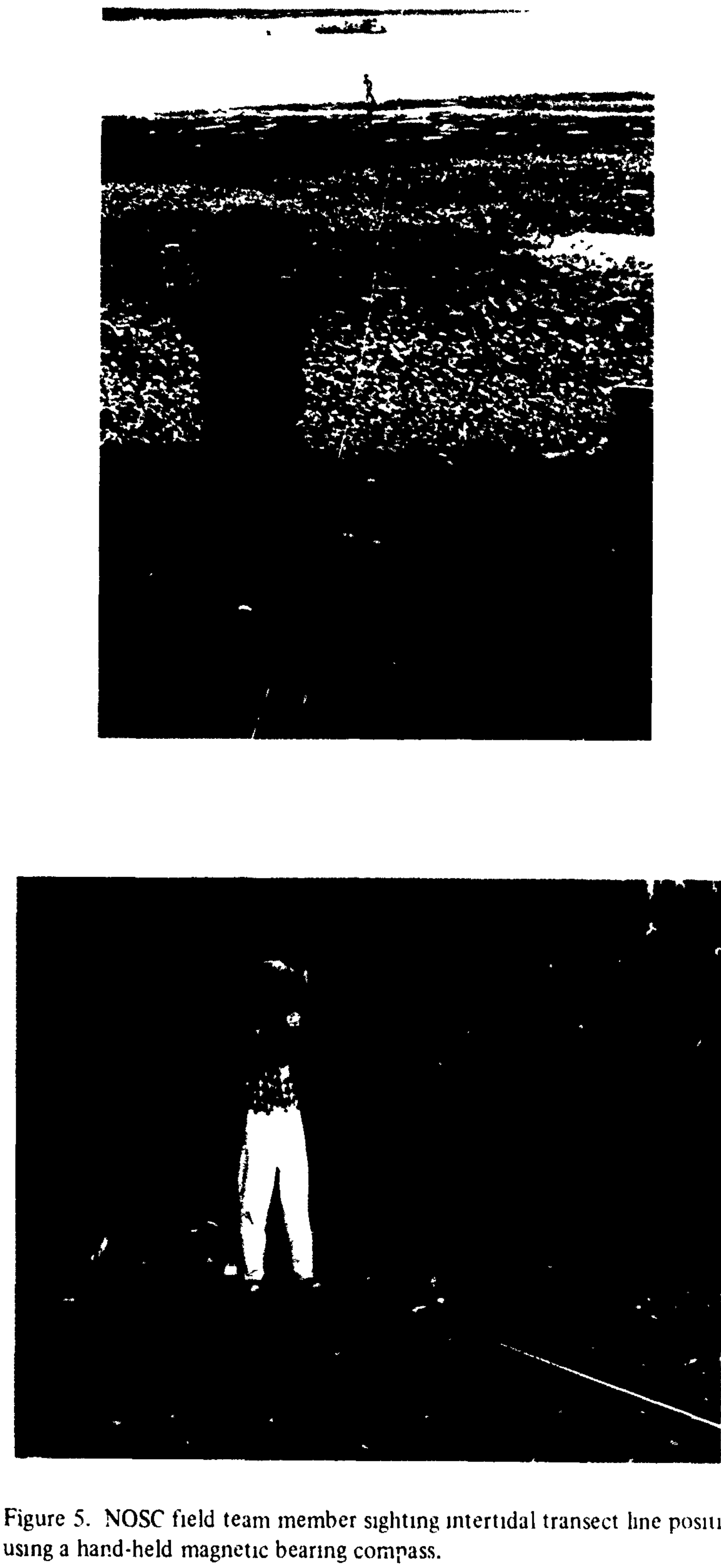

Figure 5. NOSC field team member sighting intertidal transect line position using a hand-held magnetic bearing compass.

along the transect line has been determined by major substratum and faunal zone stratification. Through careful field observations of faunal and substrata types, subtle yet recognizable intertidal zonation patterns have been identified along Hood Canal shorelines. Dig locations remained within the same intertidal zones for year-to-year comparisons among surveys.

As in previous surveys, a one-tenth of a square metre quadrat was pushed into the substratum to delineate the area to be sampled and to prevent sidewall collapse during digging activities. Material (clams, marine plants, stones, pea gravel, sand, silt, etc.) was removed to a depth of 45 cm and placed in a large cylindrical (1 m diameter by 1 m high) galvanized tub with the bottom removed. Three removable stainless steel screens with mesh sizes of 18 mm, 6 mm and 2 mm from top to bottom, respectively, were contained within this slightly cone-shaped cylinder. The amount of time required to sample a tenth of a square metre dig was a function of substratum type; however, an average field time has been calculated at 25 minutes per dig. This estimate includes digging, screening, bagging and labeling the sample. Obviously, a location with a large percentage of pea gravel in the substratum required longer to screen than an area with coarse grain sand, which filters rapidly and efficiently. The smallest screen (2 mm) retains juvenile bivalves which are important to recruitment estimates. During the most recent surveys, two of the 2-mm mesh (bottom) screens were used in an alternating fashion to facilitate the time-consuming fine screening process. This procedure allows examination of one 2-mm screen while another intertidal dig is in process. Normally, four field team members performed intertidal field sampling at a rate of one station per day during low tide periods.

Bivalves were identified to species, measured (greatest shell length) and enumerated. Useful taxonomic references (including descriptions and dichotomous keys) consulted during SUBASE Bangor intertidal monitoring surveys are found in references 25, 27-33. Commercial clam species of harvestable size ($\geqslant$ 30 mm) were weighed on a triple beam balance to determine wet biomass value. If a dig contained $\geqslant 277$ gr/0.1m^2 (i.e. 0.5 lb/ft^2) of commercially important species, it was considered of commercial value (Washington State Shellfish Laboratory, personal communication).

The density of commercial clams for each species was determined for each station by totaling the number of clams of commercial size and dividing by the area sampled. These data were normalized by calculating the densities only from digs containing commercial clam species. Total wet biomass was determined for each station and each selected commercial or recreational species. These data are reported as mean biomass in kilograms per square

[27] Cornwall, IE, Barnacles of British Columbia, British Columbia Provincial Museum Handbook 7, 69p, 1970

[28] Griffith, LM, The Intertidal Univalves, British Columbia Provincial Museum Handbook 26. 101p, 1975

[29] Kozloff, EN, Seashore Life of Puget Sound, the Strait of Georgia, and the San Juan Archipelago, University of Washington Press, 281p, 1973

[30] Kozloff, EN, Keys to the Marine Invertebrates of Puget Sound, the San Juan Archipelago, and Adjacent Regions, University of Washington Press, 226p, 1974

[31] Quayle, DB The Intertidal Bivalves of British Columbia, British Columbia Provincial Museum Handbook 17, 104p, 1973

[32] Dunnill, RM, and Ellis, DV, Recent Species of the genus *Macoma* (Pelecypoda) in British Columbia, National Museum of Ottawa, Canada, Natural History Papers, vol 45, p 1-35, 1969

[33] Ricketts, EF and Calvin, J, Between Pacific Tides, 4th ed, 614p, Stanford University Press, 1968

metre for comparative purposes. Additionally, the total number of clams in the commercial (i.e. $\geqslant$ 30 mm) and subcommercial (i.e. $\leqslant$ 29.9 mm) size ranges was calculated for each species, dig site and station. The subcommercial category was further subdivided by counting the number of clams 10 mm or smaller in length. This group consisted of juvenile bivalves which settled out of the plankton within the previous year. These young-of-the-year (YOY) data are useful to document recruitment of important commercial species of bivalves along SUBASE Bangor.

To enhance statistical validity, a minimum of two replicate digs were performed at each biological zone (which generally equates to a range of tidal heights). Data from these samples were averaged for each tidal region and summarized by species. Intertidal bivalve abundance and density were treated separately by station and by year.

During intertidal transect surveys, oyster abundance data were recorded for oysters present in one-tenth of a square metre quadrat samples at each station. Enumeration of oysters less than 2 inches (5.08 cm) long and equal to or greater than 2 inches was recorded. Previous surveys (ref 3) established a 2-inch minimum size to differentiate between commercial and non-commercial dimensions, a more realistic commercially harvestable size is considered to be 3 inches (7.62 cm). This redefined criterion has been accepted and used by SUBASE Bangor personnel. During June-July 1981, all existing oyster beds along SUBASE Bangor shorelines were surveyed by Mr. Donald Morris and Mr. Edward Cadera, fish and wildlife specialists. Oyster bed length and width parameters were measured using transect tapes. Random samples of oysters contained within a 0.1-square-metre area circular quadrat ring were counted. Width measurements and random ring toss counts were performed every 30 metres along the bed length. Furthermore, at each bed width site, counts were obtained along the upper, middle and lower areas of established oyster beds. Numerical data for commercial-size (equal to or greater than 3 inches) and noncommercial-size (less than 3 inches in length) oysters were tabulated and summarized for each site (see figure 6). An oyster resource management plan was developed by Don Morris, SUBASE Bangor fish and wildlife specialist, and is included as appendix C.

RESULTS AND DISCUSSION

Intertidal bivalve data were collected from seven environmental monitoring stations along Hood Canal during 1979, 1980 and 1981 surveys. Station beach profiles, substrata types, location of dig sites, biotic and tidal reference heights are shown in figures 7 through 13. Vertical lines on the figures indicate major substrata delineations. These figures illustrate a variety of beach slopes, faunal and floral zonation patterns and types of substrata which are present along SUBASE Bangor waterfront areas.

Bivalve abundance, distribution and biomass data from 1979, 1980 and 1981 surveys are presented in a specific-to-general sequence. Annual bivalve density data, by species, for each tidal height are presented in tables 9 through 15. A discussion of station-specific intertidal bivalve parameters is followed by summary data which describe combined species, station and yearly survey patterns. Length-frequency data for major bivalve species are listed in appendix D.

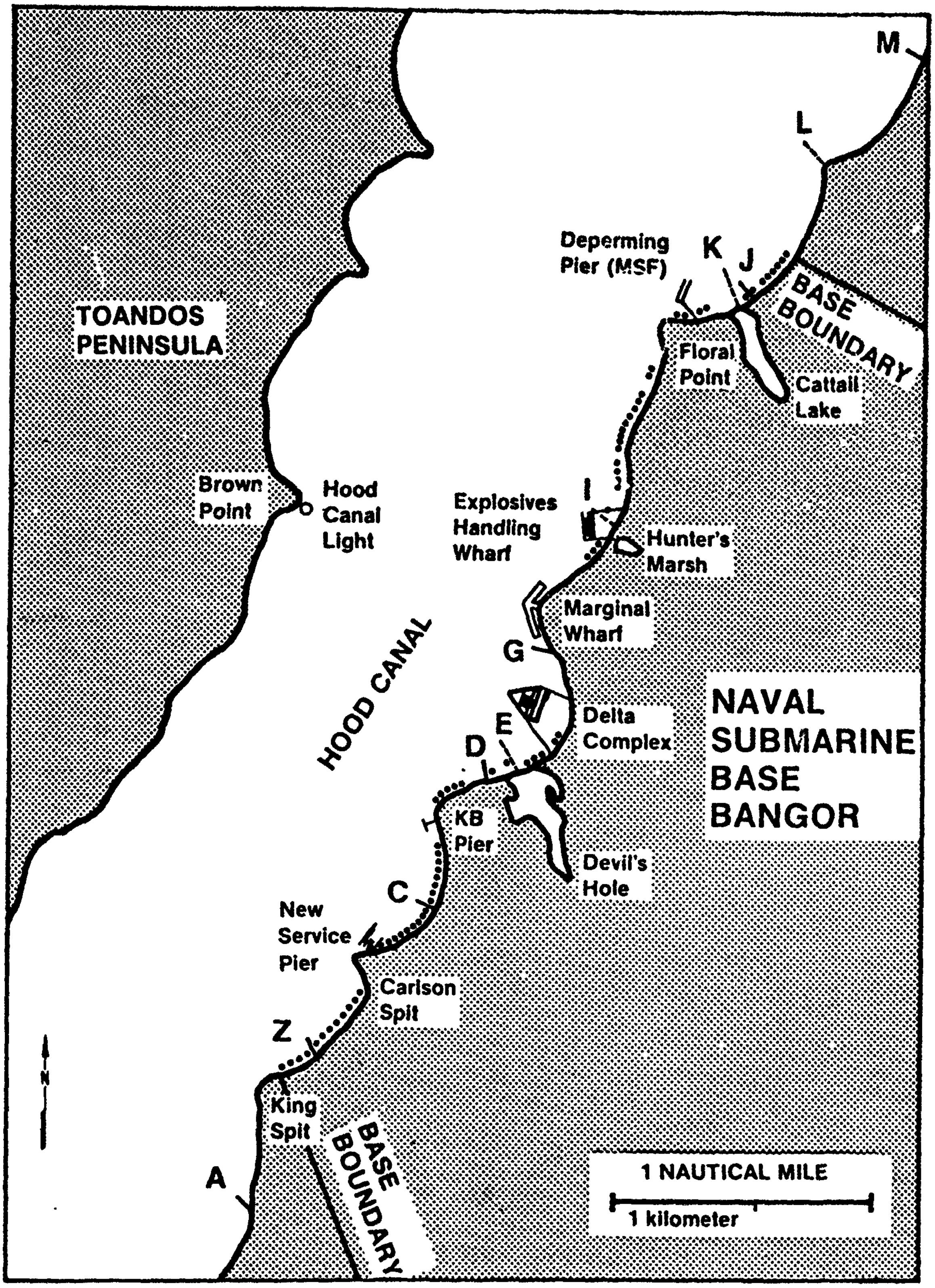

Figure 6. Oyster beds along SUBASE Bangor surveyed June-July, 1981. Oyster beds shown by dots.

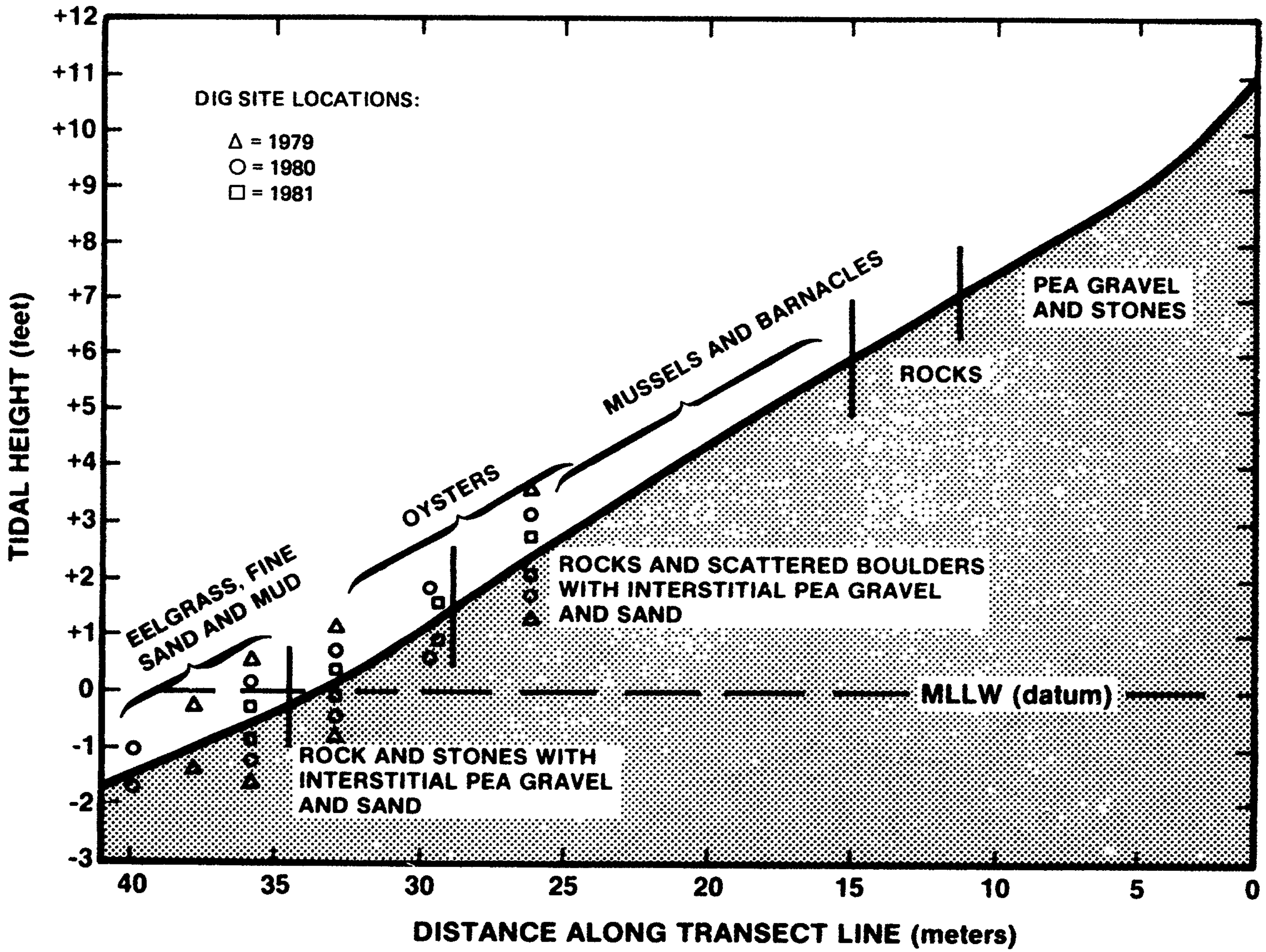

Figure 7. Integrated beach profile: Station A.

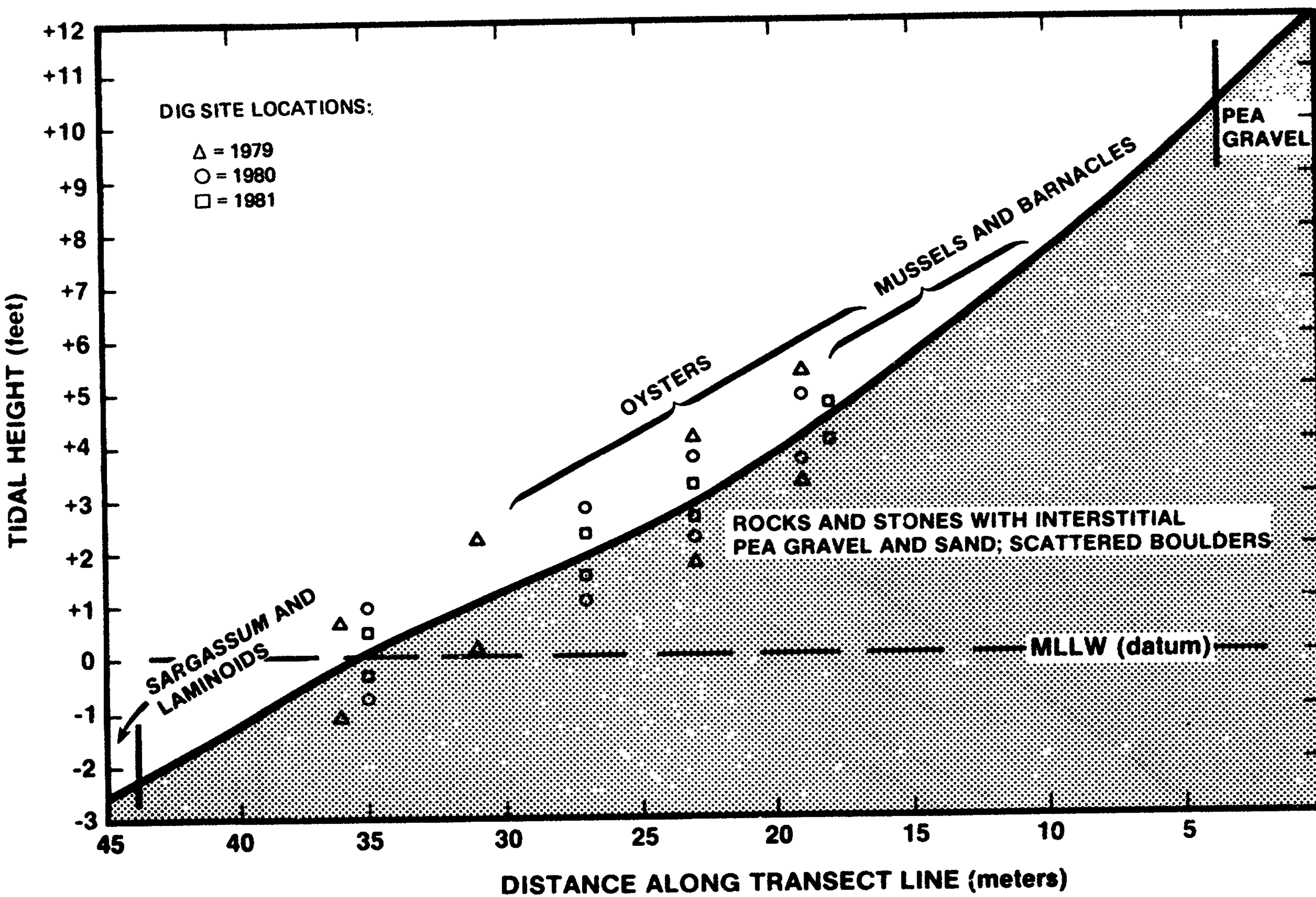

Figure 8. Integrated beach profile: Station Z.

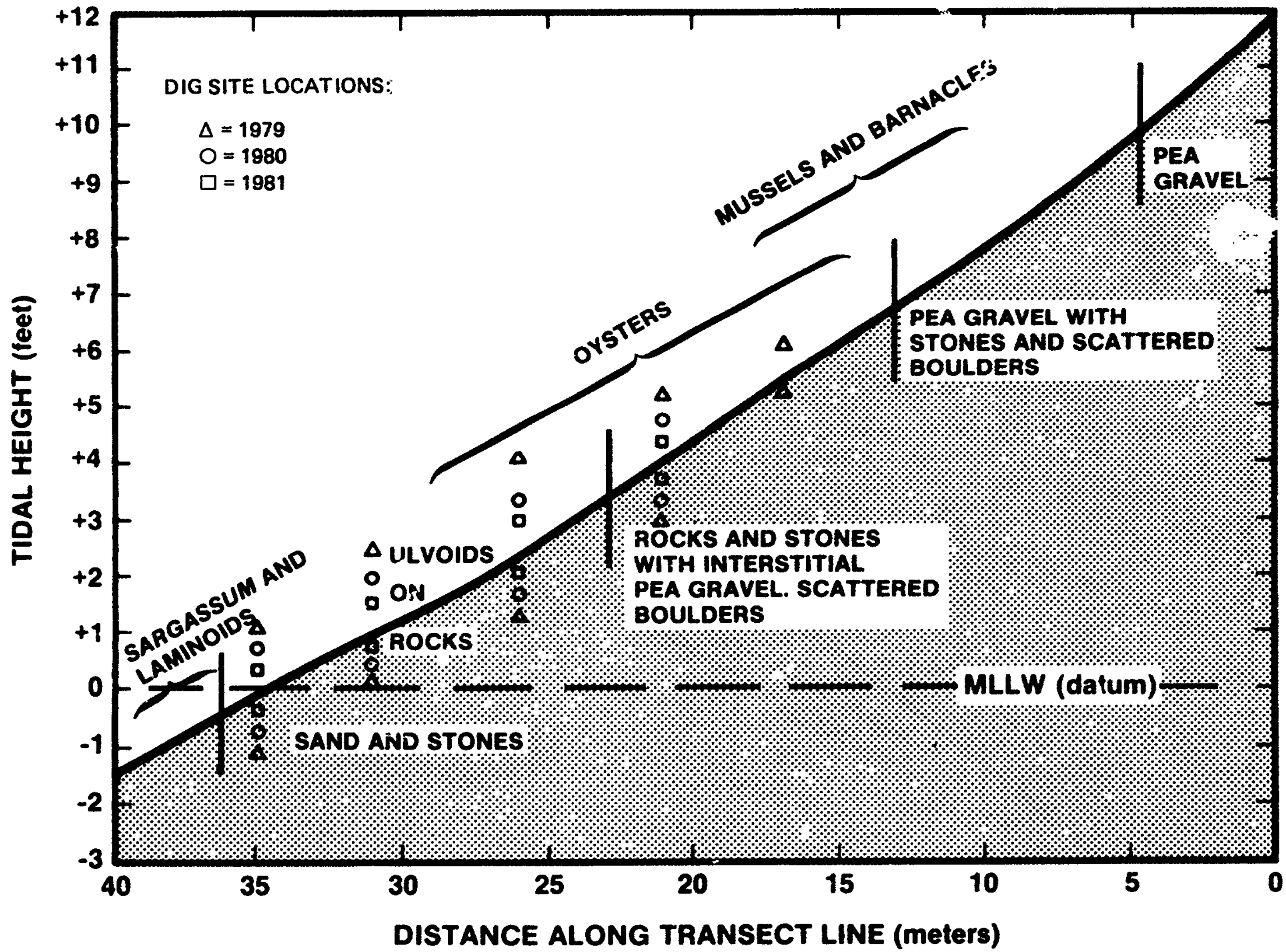

Figure 9. Integrated beach profile: Station C.

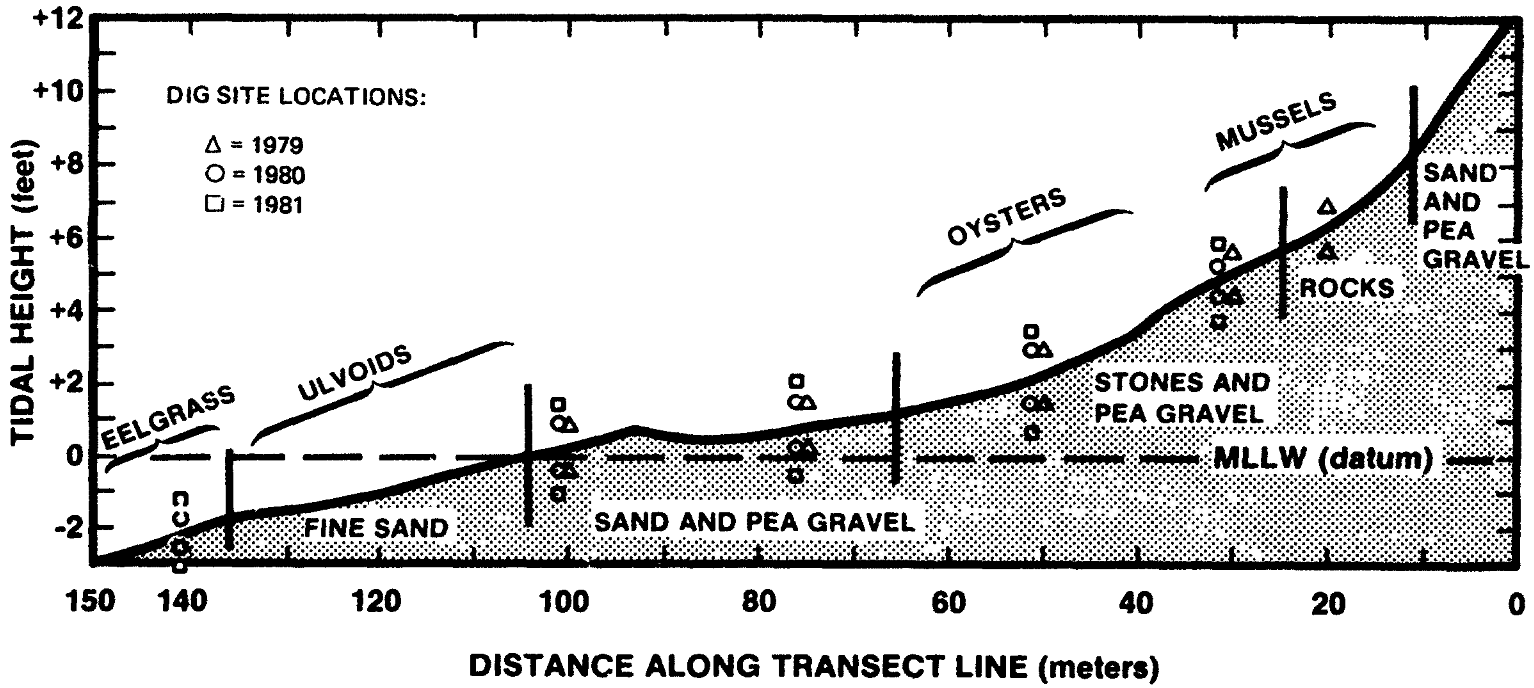

Figure 10. Integrated beach profile: Station D.

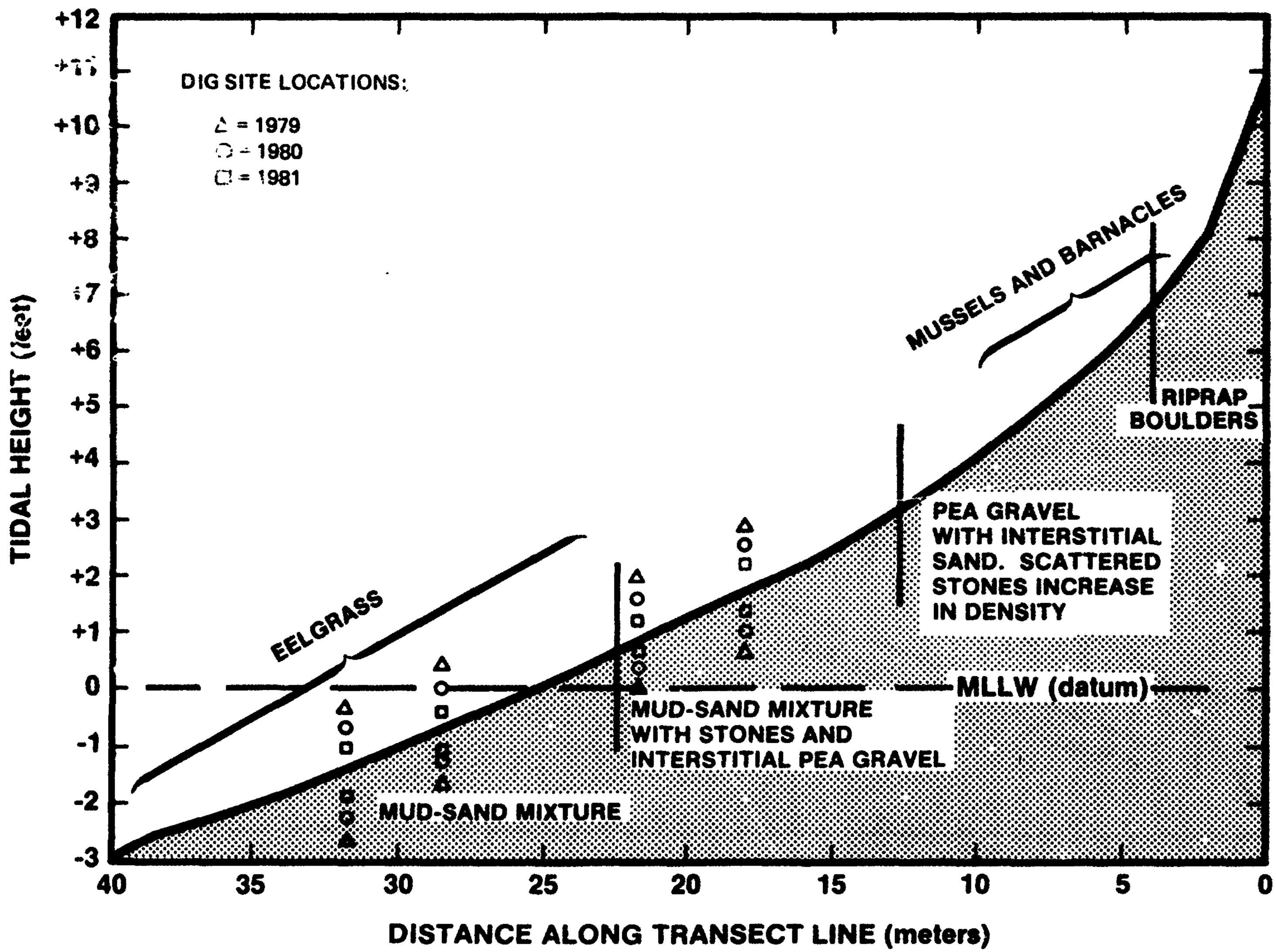

Figure 11. Integrated beach profile: Station G.

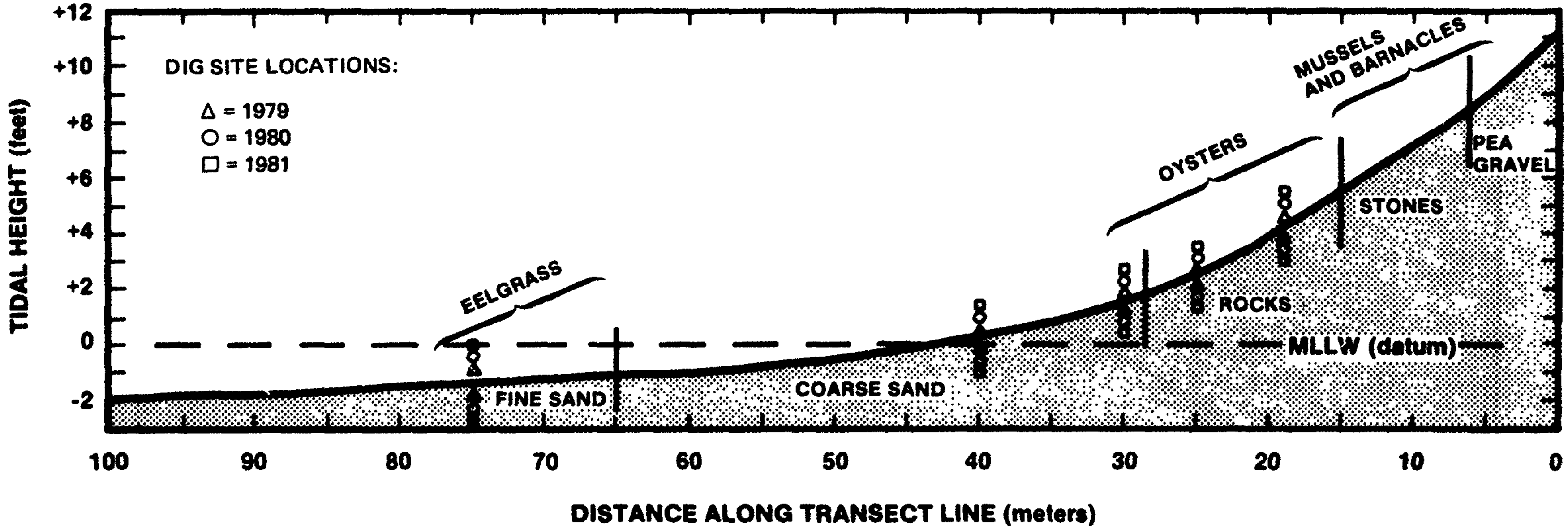

Figure 12. Integrated beach profile: Station J.

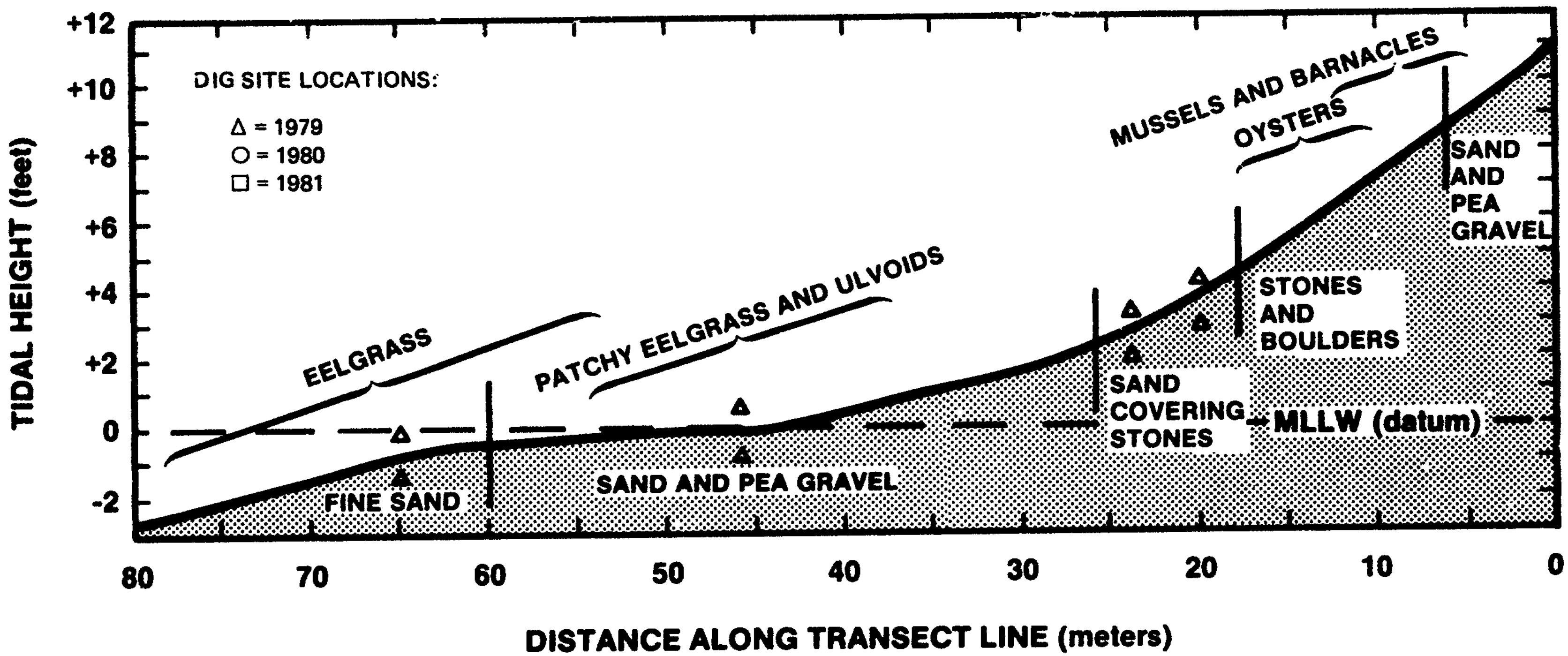

Figure 13. Integrated beach profile: Station M.

Tidal Ht (ft)/Year	*Protothaca staminea*	*Tapes japonica*	*Saxidomus giganteus*	*Tresus nuttallii*	*Tresus capax*	*Mya arenaria*	*Clinocardium nuttallii*
	Species						
+2.50/1979	5.00 (5.00)	0.00 (5.00)	NP	NP	NP	NP	NP
1980	10.00 (0.00)	NP	0.00 (10.00)	NP	NP	NP	NP
1981	0.00 (15.00)	NP	NP	NP	NP	NP	NP
+1.25/1980*	80.00 (45.00)	NP	5.00 (0.00)	NP	NP	5.00 (0.00)	NP
1981	15.00 (30.00)	NP	NP	NP	NP	NP	0.00 (5.00)
0.00/1979	110.00 (25.00)	NP	45.00 (25.00)	NP	NP	NP	0.00 (5.00)
1980	60.00 (10.00)	NP	90.00 (5.00)	NP	NP	NP	0.00 (5.00)
1981	45.00 (15.00)	NP	75.00 (5.00)	NP	NP	NP	NP
-0.50/1979	30.00 (25.00)	NP	95.00 (35.00)	NP	5.00 (0.00)	NP	0.00 (5.00)
1980	40.00 (15.00)	NP	195.00 (15.00)	NP	NP	5.00 (0.00)	0.00 (20.00)
1981	20.00 (0.00)	NP	45.00 (10.00)	NP	NP	NP	0.00 (10.00)
-1.25/1979*	10.00 (20.00)	NP	110.00 (0.00)	NP	NP	NP	5.00 (5.00)
-1.50/1980*	15.00 (0.00)	NP	100.00 (0.00)	NP	10.00 (0.00)	10.00 (0.00)	0.00 (60.00)

NP = Not present.

Frequency = Average number of commercial-size (ie ≥30mm) or subcommercial individuals (in parentheses) for each tidal height.

*= No data for years not listed (not surveyed).

Table 9. Intertidal bivalve species frequency: Station A. (number/square metre)

Tidal Ht (ft)/Year	*Protothaca staminea*	*Tapes japonica*	*Saxidomus giganteus*	*Tresus nuttallii*	*Tresus capax*	*Mya arenaria*	*Clinocardium nuttallii*
	Species						
+4.50/1979	30.00 (25.00)	15.00 (160.00)	0.00 (5.00)	NP	NP	NP	NP
1980	35.00 (45.00)	15.00 (80.00)	5.00 (0.00)	NP	NP	NP	NP
1981	0.00 (25.00)	5.00 (0.00)	NP	NP	NP	NP	NP
+3.00/1979	55.00 (105.00)	70.00 (115.00)	5.00 (0.00)	NP	NP	NP	NP
	105.00 (45.00)	15.00 (35.00)	10.00 (0.00)	NP	NP	NP	NP
	50.00 (10.00)	NP	10.00 (0.00)	NP	NP	NP	NP
+1.75/1979	115.00 (50.00)	20.00 (35.00)	90.00 (5.00)	NP	NP	5.00 (0.00)	NP
1980	80.00 (15.00)	NP	50.00 (0.00)	NP	NP	NP	NP
1981	50.00 (15.00)	NP	45.00 (0.00)	NP	NP	NP	NP
0.00/1979	20.00 (0.00)	NP	15.00 (5.00)	NP	NP	NP	NP
1980	5.00 (5.00)	NP	20.00 (0.00)	NP	NP	NP	NP
1981	10.00 (5.00)	NP	5.00 (15.00)	NP	NP	NP	NP

NP = Not present.

Frequency = Average number of commercial-size (ie ⩾30mm) or subcommercial individuals (in parentheses) for each tidal height.

Table 10. Intertidal bivalve species frequency: Station Z. (number/square metre)

Tidal Ht (ft)/Year	Species *Protothaca staminea*	*Tapes japonica*	*Saxidomus giganteus*	*Tresus nuttallii*	*Tresus capax*	*Mya arenaria*	*Clinocardium nuttallii*
+5.25/1979*	NP	NP	NP	NP	NP	NP	NP
+3.75/1979	5.00 (45.00)	5.00 (40.00)	NP	NP	NP	NP	NP
1980	55.00 (20.00)	10.00 (10.00)	NP	NP	NP	5.00 (0.00)	NP
1981	10.00 (130.00)	NP	0.00 (5.00)	NP	NP	NP	NP
+2.50/1979	200.00 (45.00)	0.00 (25.00)	60.00 (5.00)	NP	NP	0.00 (15.00)	NP
1980	185.00 (35.00)	15.00 (5.00)	20.00 (5.00)	NP	NP	NP	NP
1981	165.00 (40.00)	NP	45.00 (0.00)	NP	NP	NP	NP
+1.00/1979	65.00 (20.00)	NP	50.00 (20.00)	NP	NP	NP	NP
1980	80.00 (15.00)	NP	75.00 (0.00)	NP	NP	NP	NP
1981	20.00 (5.00)	NP	35.00 (10.00)	NP	NP	NP	NP
0.00/1979	20.00 (5.00)	NP	25.00 (0.00)	NP	NP	NP	NP
1980	25.00 (10.00)	NP	15.00 (5.00)	NP	NP	NP	NP
1981	5.00 (10.00)	NP	55.00 (0.00)	NP	NP	NP	NP

NP = Not present.

Frequency = Average number of commercial-size (ie ⩾30mm) or subcommercial individuals (in parentheses) for each tidal height.

*= No data for years not listed (not surveyed).

Table 11. Intertidal bivalve species frequency: Station C. (number/square metre)

Tidal Ht (ft)/Year	Species *Protothaca staminea*	*Tapes japonica*	*Saxidomus giganteus*	*Tresus nuttallii*	*Tresus capax*	*Mya arenaria*	*Clinocardium nuttallii*
+6.25/1979*	NP	10.00 (60.00)	NP	NP	NP	15.00 (15.00)	NP
+5.00/1979	120.00 (155.00)	5.00 (10.00)	100.00 (105.00)	NP	NP	NP	0.00 (5.00)
1980	0.00 (30.00)	75.00 (110.00)	0.00 (5.00)	NP	NP	5.00 (0.00)	NP
1981	0.00 (5.00)	90.00 (5.00)	NP	NP	NP	5.00 (5.00)	NP
+2.00/1979	35.00 (65.00)	NP	45.00 (65.00)	NP	NP	10.00 (0.00)	15.00 (0.00)
1980	90.00 (180.00)	15.00 (10.00)	45.00 (105.00)	NP	NP	NP	0.00 (10.00)
1981	20.00 (195.00)	20.00 (5.00)	40.00 (140.00)	NP	NP	0.00 (5.00)	NP
+1.00/1979	75.00 (25.00)	NP	185.00 (70.00)	NP	NP	0.00 (5.00)	NP
1980	55.00 (10.00)	NP	45.00 (10.00)	NP	NP	5.00 (0.00)	NP
1981	55.00 (75.00)	NP	50.00 (25.00)	NP	NP	NP	NP
0.00/1979	5.00 (5.00)	NP	25.00 (25.00)	NP	NP	NP	NP
1980	40.00 (45.00)	NP	30.00 (10.00)	NP	NP	NP	15.00 (30.00)
1981	25.00 (40.00)	NP	55.00 (40.00)	NP	NP	NP	5.00 (5.00)
-2.25/1980*	0.00 (5.00)	NP	55.00 (10.00)	NP	NP	NP	5.00 (5.00)
1981	15.00 (5.00)	NP	45.00 (5.00)	NP	5.00 (5.00)	NP	NP

NP = Not present.

Frequency = Average number of commercial-size (ie ≥30mm) or subcommercial individuals (in parentheses) for each tidal height.

*= No data for years not listed (not surveyed).

Table 12. Intertidal bivalve species frequency: Station D. (number/square metre)

Tidal Ht (ft)/Year	*Protothaca staminea*	*Tapes japonica*	*Saxidomus giganteus*	*Tresus nuttallii*	*Tresus capax*	*Mya arenaria*	*Clinocardium nuttallii*
	Species						
+3.00/1979*	NP	NP	NP	NP	NP	NP	NP
+1.75/1979	45.00 (0.00)	NP	0.00 (15.00)	NP	NP	NP	NP
1980	20.00 (0.00)	NP	NP	NP	NP	5.00 (0.00)	NP
1981	0.00 (15.00)	NP	5.00 (0.00)	NP	NP	NP	NP
+0.75/1979	NP	NP	NP	NP	10.00 (0.00)	NP	5.00 (0.00)
1980	NP	NP	5.00 (0.00)	NP	NP	NP	15.00 (5.00)
1981	5.00 (0.00)	NP	15.00 (0.00)	NP	NP	NP	0.00 (10.00)
-0.75/1979	5.00 (10.00)	NP	20.00 (0.00)	15.00 (0.00)	NP	NP	NP
1980	5.00 (0.00)	NP	5.00 (0.00)	NP	5.00 (0.00)	NP	5.00 (5.00)
1981	NP	NP	25.00 (5.00)	15.00 (0.00)	NP	NP	5.00 (0.00)
-1.50/1979	NP	NP	30.00 (5.00)	5.00 (0.00)	5.00 (0.00)	NP	5.00 (0.00)
1980	5.00 (0.00)	NP	25.00 (0.00)	NP	NP	NP	0.00 (10.00)
1981	5.00 (0.00)	NP	30.00 (10.00)	NP	5.00 (0.00)	NP	NP

NP = Not present.

Frequency = Average number of commercial-size (ie ≥30mm) or subcommercial individuals (in parentheses) for each tidal height.

*= No data for years not listed (not surveyed).

Table 13. Intertidal bivalve species frequency: Station G. (number/square metre)

Tidal Ht (ft)/Year	*Protothaca staminea*	*Tapes japonica*	*Saxidomus giganteus*	*Tresus nuttallii*	*Tresus capax*	*Mya arenaria*	*Clinocardium nuttallii*
+4.50/1979	15.00 (45.00)	5.00 (5.00)	NP	NP	NP	0.00 (10.00)	NP
1980	5.00 (20.00)	0.00 (10.00)	NP	NP	NP	NP	NP
1981	5.00 (85.00)	0.00 (5.00)	NP	NP	NP	0.00 (5.00)	NP
+2.50/1979	5.00 (50.00)	NP	10.00 (30.00)	NP	NP	NP	0.00 (5.00)
1980	10.00 (15.00)	NP	NP	NP	NP	NP	NP
1981	10.00 (5.00)	NP	20.00 (5.00)	NP	NP	NP	5.00 (5.00)
+1.60/1979	0.00 (25.00)	NP	5.00 (0.00)	NP	NP	NP	0.00 (5.00)
1980	10.00 (15.00)	NP	NP	NP	NP	NP	NP
1981	0.00 (5.00)	NP	5.00 (0.00)	NP	NP	NP	0.00 (5.00)
0.00/1979	0.00 (65.00)	NP	0.00 (60.00)	NP	NP	NP	5.00 (0.00)
1980	0.00 (15.00)	NP	NP	NP	5.00 (0.00)	NP	0.00 (20.00)
1981	0.00 (5.00)	NP	NP	NP	NP	NP	0.00 (5.00)
-1.60/1979	5.00 (0.00)	NP	0.00 (5.00)	NP	NP	NP	NP
1980	NP	NP	NP	NP	NP	NP	0.00 (20.00)
1981	NP	NP	NP	NP	0.00 (5.00)	NP	NP

NP = Not present.

Frequency = Average number of commercial-size (ie ⩾30mm) or subcommercial individuals (in parentheses) for each tidal height.

Table 14. Intertidal bivalve species frequency: Station J. (number/square metre)

Tidal Ht (ft)/Year	*Protothaca staminea*	*Tapes japonica*	*Saxidomus giganteus*	*Tresus nuttallii*	*Tresus capax*	*Mya arenaria*	*Clinocardium nuttallii*
+3.50/1979*	15.00 (10.00)	NP	5.00 (10.00)	NP	NP	10.00 (0.00)	NP
+2.50/1979*	15.00 (95.00)	0.00 (5.00)	5.00 (25.00)	NP	NP	NP	0.00 (5.00)
0.00/1979*	0.00 (15.00)	NP	0.00 (15.00)	NP	NP	NP	15.00 (20.00)
-1.00/1979*	0.00 (5.00)	NP	NP	NP	NP	NP	5.00 (5.00)

NP = Not present.

Frequency = Average number of commercial-size (ie ⩾30mm) or subcommercial individuals (in parentheses) for each tidal height.

* = No data for years not listed (not surveyed).

Station surveyed in 1979 only.

Table 15. Intertidal bivalve species frequency: Station M. (number/square metre)

A comprehensive data base for intertidal bivalve populations along SUBASE Bangor has been established through 11 surveys during the past eight years (1973-1981). These extensive baseline data are necessary for detecting and evaluating potentially abnormal changes in bivalve populations, should they occur. Since 1973, natural fluctuations in bivalve populations adjacent to SUBASE Bangor have been observed.

Station A

Intertidal bivalve samples were collected at Station A between +2.5- and −1.5-foot tidal heights during 1979, 1980 and 1981 surveys. This off-base station is representative of a typical intertidal beach area along northern Hood Canal (figure 2). A moderately steep beach slope (1:11 gradient) consisting of rocks and cobbles with interstitial pea gravel in the upper intertidal region is covered by scattered barnacles and mussels in the mid-intertidal region (about +5.0-foot level). A well-developed oyster zone (at +3.5- to +1.0-foot levels) is present. At about the zero tidal level the substratum becomes fine sand and mud covered by an eelgrass (*Zostera marina*) bed which extends subtidally to a depth of about 8 metres (figure 7). This exposed beach is subjected to moderate wave and wind action throughout the year.

During the 1979 intertidal survey at station A, *Protothaca staminea* (native littleneck clams) were most abundant at the +1.25-foot to zero tidal level and *Saxidomus giganteus* (butter clams) were densest lower intertidally at about the −1.25-foot level (table 9). Station commercial bivalve biomass estimates were 1.42 kg/m^2 for native littleneck clams, 6.84 kg/m^2 for butter clams, 1.02 kg/m^2 for *Tresus capax* (horseneck clams) and 0.24 kg/m^2 for *Clinocardium nuttallii* (basket cockles). Commercial size bivalves ($\geq$ 30 mm in greatest dimension) were represented by the following station percentages: 36.9% for native littlenecks, 59.5% for butter clams, 2.4% for horseneck clams and 1.2% for basket cockles during 1979 sampling activities. Juvenile YOY size ($\leq$ 10 mm) native littleneck clams, butter clams and basket cockles represented 30%, 20% and 50% of the individuals collected for each species, respectively. These data indicate that recruitment is occurring and that a reproducing assemblage of commercially important bivalves is present at this station.

During the 1980 survey, native littlenecks were most prevalent at the +1.25-foot tidal level. Butter clams and basket cockles were concentrated at the −0.5-foot level; however, these species were also collected within the +1.25- to −1.5-foot tidal region. Commercial-size bivalve biomass data were highest at this station during the 1980 survey for native littleneck clams (1.88 kg/m^2) and butter clams (11.41 kg/m^2). Commercial-size bivalves represented the following percentages during 1980 sampling activities: 32.5% for native littleneck clams, 62.6% for butter clams, 1.6% for horseneck clams and 3.3% for *Mya arenaria* (eastern softshell clams). Recruitment was high for basket cockles (100% of individuals collected were $\leq$ 10 mm) and less for native littleneck clams and butter clams, 17% and 4%, respectively.

During the 1981 intertidal bivalve survey, both native littleneck clams and butter clams were most concentrated at the zero tidal level. Biomass estimates were somewhat reduced from the previous two years for native littleneck clams at 0.78 kg/m^2 and butter clams at 3.44 kg/m^2. Butter clams again represented 60% of the commercial-size bivalves

collected at this station while native littleneck clams accounted for the remaining 40%. Recruitment for basket cockles, butter clams and native littleneck clams was observed during the 1981 survey, YOY size individuals composing 100%, 7% and 14% of the total for each respective species.

During this three-year period, the average biomass values for commercial-size bivalves, by species, present at station A were: 1.36 kg/m^2 for *P. staminea*, 7.23 kg/m^2 for *S. giganteus*, 0.46 kg/m^2 for *T. capax*, 0.09 for *M. arenaria* and 0.24 kg/m^2 for *C. nuttallii*. This station had the densest aggregation of butter clams of any station sampled during the three-year period. Consistent with previous observations, *Tapes japonica* (Manila littleneck clams) were essentially absent at station A. Annual recruitment for major bivalve species was observed at this station.

Station Z

Intertidal bivalve samples were collected between zero and +4.5-foot tidal heights during 1979, 1980 and 1981. Station Z is located about a kilometre north of station A (see figure 2). This on-base station possesses a relatively steep beach gradient (1:10). Mussels and barnacles are abundant in the higher intertidal region (+6.5 to +4.0 feet) and an extensive oyster bed is present at this station (+4.5 to +1.0 feet). No eelgrass bed is evident at the zero to -2.0-foot tidal level at station Z. Major beach substrata consist of scattered boulders, rocks and stones with interstitial pea gravel (figure 8). This station is moderately protected from south wind and wave conditions by King Spit to the south.

During the 1979 survey, native littleneck and butter clams were densest at the +1.75-foot tidal level. Manila littleneck clams were most abundant at the +3.0-foot level (table 10). A single eastern soft-shell clam was collected at the +1.75-foot tidal level during 1979. Biomass estimates for integrated tidal height bivalve samples at station Z were: 1.20 kg/m^2 for native littleneck clams, 0.30 kg/m^2 for Manila littleneck clams and 1.71 kg/m^2 for butter clams. Commercial-size bivalves were represented by the following percentages: 56.1% for native littleneck clams, 20.4% for Manila littleneck clams, 22.5% for butter clams and 1.0% for eastern soft-shell clams. Percentages of juvenile ($\leqslant$ 10 mm) in the total station collections during 1979 were 4% for native littlenecks, 4% for butter clams and 8% for Manila littleneck clams. These bivalve recruitment data reflect low values for station Z during the 1979 survey.

During the 1980 intertidal survey, native littleneck and butter clams were concentrated at the +3.0- to +1.75-foot tidal levels. Manila littleneck clams were rather evenly collected over the +4.5- to +1.75-foot tidal range during 1980. Station biomass values were: 1.0 kg/m^2 for native littlenecks, 0.11 kg/m^2 for Manila littleneck clams and 1.95 kg/m^2 for butter clams. Commercial-size bivalve percentages were 66.2% for native littlenecks. 8.8% for Manila clams and 25.0% for butter clams. During 1980 sampling, bivalve recruitment was observed for native littleneck clams (22% for all individuals were equal to or less than 10 mm size) and Manila littleneck clams (31%). However, no juvenile butter clams were collected at station Z during 1980 survey activities.

During the 1981 survey, native littlenecks occurred from zero to +3.0-foot tidal levels. Manila clams were collected only from the +4.5-foot tidal level during 1981. Butter clams were densest at the +1.75-foot tidal level. Station biomass values were somewhat reduced when compared with the previous two years: 0.57 kg/m^2 for native littleneck clams,

0.02 kg/m^2 for Manila clams and 1.28 kg/m^2 for butter clams. Species percentages of commercial-size bivalves for 1981 samples were: 62.9% for native littlenecks, 2.9% for Manila clams and 34.2% for butter clams. Juvenile native littleneck and butter clams each represented 13% of total individuals for each species. No Manila littleneck clam juveniles ($\leqslant$ 10 mm) were collected during the 1981 survey at station Z.

During 1979, 1980 and 1981 surveys the average biomass values for commercial-size bivalves at station Z were: 0.97 kg/m^2 for *P. staminea*, 0.14 kg/m^2 for *T. japonica* and 1.65 kg/m^2 for *S. giganteus*. This station ranks fifth out of seven during the three-year period with respect to commercial clam biomass. Recruitment of major bivalve species was low to sporadic during this period.

Station C

Intertidal bivalve samples were collected between zero and +5.5-foot tidal heights at station C during 1979, 1980 and 1981 surveys. Station C is located in Carlson Cove between KB Pier and the New Service Pier (see figure 2). This station was potentially vulnerable to impacts from construction activities at NSP during this sampling period. The measured beach gradient at this station is 1:9.73, the steepest gradient of all seven intertidal sampling beaches along the SUBASE Bangor waterfront area (figure 9). The upper intertidal region at station C consists of cobbles and stones with scattered boulders. An underlying layer of interstitial sand and pea gravel is present down to the +2.5-foot tidal level. Rocks and interstitial sand compose the substratum in mid and lower intertidal regions at this station. Scattered eelgrass is evident at the lowest tidal levels. This naturally sheltered cove became even more protected from wind and wave after the New Service Pier was built in 1981.

During the 1979 intertidal survey, native littleneck clams were most concentrated at the +2.5-foot tidal level. Butter clams were collected from zero to +2.5-foot tidal heights and the densest concentration occurred at the +2.5-foot level (table 11). Most Manila clams were collected from the +3.75-foot tidal level. Several juvenile eastern soft-shell clams were collected at the +2.5-foot level during 1979. Station biomass estimates for commercial-size bivalves were: 1.42 kg/m^2 for native littleneck clams, 0.01 kg/m^2 for Manila clams, 2.56 kg/m^2 for butter clams and 0.02 kg/m^2 for eastern soft-shell clams. Percentages of commercial-size clams, by species, collected in 1979 at station C were: 66.7% for native littleneck clams, 1.1% for Manila littleneck clams, 31.1% for butter clams and 1.1% for eastern soft-shell clams. Juvenile commercial species recruitment was represented by 10% of native littlenecks, 50% of Manila clams and 7% of butter clams.

In 1980, native littleneck clams were concentrated again at the +2.5-foot tidal level at station C. Manila clams were collected in equal abundance from +2.5- and +3.75-foot tidal levels. Butter clams were concentrated at the +1.0-foot tidal height. Biomass estimates for commercial species at station C in 1980 were: 1.85 kg/m^2 for native littleneck clams, 0.1 kg/m^2 for Manila clams and 2.69 kg/m^2 for butter clams. A single eastern soft-shell clam was collected at +3.75-foot tidal level. Percentages of commercial-size bivalves collected during 1980 were: 71.1%, 5.2%, 22.7% and 1.0% for native littleneck clams, Manila clams,

butter clams and eastern soft-shell clams, respectively. Commercial clam species recruitment was represented by the following percentages of total individuals for each species: 11% for native littlenecks, 13% for Manila clams and 8% for butter clams during 1980 collections.

During the 1981 intertidal survey, native littleneck clams were again most numerous at the +2.5-foot tidal level. No Manila clams were collected from this station in 1981. Butter clams were most concentrated at the zero tidal level; however, this species was present in nearly equal abundance from +2.5 feet down to the zero tidal level. Station biomass estimates for commercial bivalves were: 0.88 kg/m^2 For native littleneck clams and 4.11 kg/m^2 for butter clams. This value was the highest biomass estimate for butter clams during the 1981 survey at all stations. Native littleneck clams represented 60% and butter clams 40% of the total bivalve individual abundance during 1981 sampling at station C. Juvenile bivalves ($\leqslant$ 10 mm) recruitment data were highest at station C during 1981 sampling, with native littleneck clams representing 17% and butter clam juveniles representing 10% of the individuals collected from each respective species.

Three-year mean biomass values at station C were: 1.38 kg/m^2 for native littleneck clams, 0.1 kg/m^2 for Manila clams, 3.12 kg/m^2 for butter clams and 0.02 kg/m^2 for eastern soft-shell clams. This station has consistently produced an abundance of commercially important bivalves. Even with the New Service Pier construction during 1979, 1980 and 1981, station C ranks only behind station A in total bivalve biomass (station averages used for comparison). A few Manila and eastern soft-shell clams have been collected from this station. No basket cockles were collected during the three-year sampling period.

Station D

Intertidal bivalve samples were collected between +6.25- and -2.25-foot tidal levels at station D during 1979, 1980 and 1981 surveys. As previously mentioned in the introduction to this report, station D was established in 1979 to replace station E. Station D is located on the southern Devil's Hole delta region (see figure 2) between KB Pier and the Delta Complex Facility. This transect extends from the high tide berm line consisting of stones, pea gravel and shell debris down to zero tidal level at about the 125-metre mark along the transect line (figure 10). The gently sloping beach gradient, measured from +6.5-foot tidal height down to -2.5-foot tidal height, is 1:45. Substratum along the mid-intertidal region consists of sand and pea gravel. Below zero tidal level, fine sand and eelgrass patches are present. A well-developed eelgrass bed begins at 130 metres along the transect line. This station is relatively sheltered from southerly wind and wave action. Station D (along with station G) is near the primary center of Trident construction activities, the Delta Complex Facility.

During the 1979 intertidal survey, native littleneck clams were collected from +5.0- to -2.25-foot tidal levels (table 12). *Tapes japonica* (Manila clams) were concentrated at the +6.25-foot tidal level during the 1979 sample collections. Butter clam concentrations were densest at the +1.0-foot level; however, commercially significant sample digs were present from -2.25- to +5.0-foot tidal levels. Eastern soft-shell clams were collected from +6.25- to +1.0-foot tidal levels, being most concentrated at the upper intertidal regions. Basket cockles were most numerous at the +2.0-foot tidal level. Biomass values for combined sample sites at station D during the 1979 survey were: 0.62 kg/m^2 for native littlenecks, 0.05 kg/m^2 for Manila clams, 1.78 kg/m^2 for butter clams, 0.07 kg/m^2 for eastern soft-shell clams and 0.18 kg/m^2 for basket cockles. Bivalve percentages observed in 1979 samples

yielded the following composition by species: 3.6% for native littleneck clams, 3.2% for Manila clams, 51.6% for butter clams, 5.4% for eastern soft-shell clams and 3.2% for basket cockles Juvenile YOY bivalve recruitment data from 1979 collections (percentages, by species, composed of individuals ≤ 10mm in maximum dimension) were: 71% for native littleneck clams, 35% for Manila littleneck clams and 64% for butter clams.

During the 1980 intertidal survey, native littleneck clams were densest at the +2.8-foot tidal level. Manila clams were concentrated at the +5.0-foot tidal level. Butter clams were quite evenly distributed from +5.0- to -2.25-foot tidal levels during the 1980 sampling period. Most juvenile butter clams (*Saxidomus giganteus*) less than 30 mm were collected at the +2.0-foot tidal height. A few eastern soft-shell clams were collected from +5.0- and +1.0-foot tidal levels. Basket cockles were most numerous in samples at the zero tidal level during 1980. Station bivalve biomass estimates were: 0.74 kg/m^2 for native littleneck clams, 0.15 kg/m^2 for Manila clams, 2 01 kg/m^2 for butter clams, 0.13 kg/m^2 for eastern soft-shell clams and 0.15 kg/m^2 for basket cockles. During the 1980 survey the following percent composition data were collected for commercial-size bivalve species: 38.5% for native littleneck clams, 18.8% for Manila clams, 36.4% for butter clams, 2.1% for eastern soft-shell clams and 4.2% for basket cockles. Percentages of juvenile commercially important bivalves (≤ 10 mm) when compared with adults of the same species were: 24% for native littleneck clams, 5% for Manila clams,, 15% for butter clams and 8% for basket cockles. Recruitment of commercially important YOY bivalves is again evident from these data.

During the 1981 intertidal survey, native littleneck clams were densest at the +1.0-foot tidal level. Manila clams were concentrated high intertidally at +5.0 feet. Butter clams were evenly distributed (about 50 individuals/square metre) from +2.0- to -2.25-foot tidal levels. *Tresus capax* (horseneck clams) were collected at station D during 1981 at the -2.25-foot tidal level. Eastern soft-shell clams were present at +5.0- and +2.0-foot tidal levels. Basket cockles were present at the zero tidal level. Combined station bivalve biomass data for 1981 estimates were. 0.57 kg/m^2 for native littleneck clams, 0.15 kg/m^2 for Manila clams, 2.28 kg/m^2 for butter clams, 0.27 kg/m^2 for horseneck clams, 0.01 kg/m^2 for eastern soft-shell clams and 0.04 kg/m^2 for basket cockles. Percentages of numerical abundance by species were: 26.7% for native littleneck clams, 25.5% for Manila clams, 44.2% for butter clams, 1.2% for horseneck clams, 1.2% for eastern soft-shell clams and 1.2% for basket cockles. Recruitment for native littlenecks (40% of all individuals were ≤ 10 mm) and butter clams (29%) was observed during the 1981 intertidal survey at station D.

During the 1979, 1980 and 1981 intertidal surveys, the mean commercial bivalve biomass values by species were: 0.64 kg/m^2 for native littleneck clams, 0.12 for kg/m^2 for Manila littleneck clams, 2.01 kg/m^2 for butter clams, 0.07 kg/m^2 for *T. capax*, 0.07 kg/m^2 for eastern soft-shell clams and 0.12 kg/m^2 for basket cockles. This station ranked fourth in overall clam biomass when compared with six other sampling stations. Species abundance and distribution for bivalves are considered more representative of the entire delta region than were data previously collected at station E. Excellent recruitment of commercial bivalve species occurred during the three-year period.

Station G

Intertidal bivalve samples were collected between +1.75- and -1.5-foot tidal levels during the period 1979, 1980 and 1981 at station G (see figure 2). A moderately steep beach

gradient (1:12) exists at this station from +6.0- to -2.0-foot tidal heights (figure 11). The upper intertidal area at station G contains large boulders and rip-rap along the initial five metres of transect distance down to the +6.0-foot tidal level. Beyond this and extending down into the +1.0-foot tidal region, the substratum is composed of stones and pea gravel with interstitial sand. Below +1.0 foot the substratum becomes a mud-sand mixture and eelgrass is present at about the zero tidal level. At about -3.0-foot tidal level a steep clay bank (approximately 25° slope or 1:2 gradient) develops and continues to a depth of 10 metres. During diving observations, this clay bank has been seen to support a population of the boring piddock clam (*Zirphaea pilsbryi*). Station G has been potentially impacted by waterfront operations at Marginal Wharf for several decades and by additional construction activities at the Delta Complex during the past several years. This station is moderately sheltered from wind and wave conditions.

During the 1979 intertidal survey, native littleneck clams were concentrated at the +1.75-foot tidal level at station G (table 13). Butter clams were densest at the -1.5-foot level. No Manila clams were present at this station. Both *T. capax* and *T. nuttallii* (horseneck clams) were commonly collected at station G at +0.75- to -1.5-foot tidal levels. Basket cockles were also collected from this tidal range. Biomass estimates for 1979 bivalve data at station G were: 0.52 kg/m^2 for native littleneck clams, 2.0 kg/m^2 for butter clams, 0.65 kg/m^2 for *T. nuttallii* and 0.26 kg/m^2 for *T. capax*, 0.87 kg/m^2 for eastern soft shell clams and 0.20 kg/m^2 for basket cockles. Percent composition by species for commercial-size bivalves were as follows: 31.3% for native littleneck clams, 31.3% for butter clams, 12.5% for *T. nuttallii*, 9.4% for *T. capax*, 9.4% for eastern soft-shell clams and 6.1% for basket cockles. Commercial bivalve species recruitment for individuals $\leqslant$ 10 mm as expressed by percentage of juveniles was: 8% for native littlenecks, 29% for butter clams and 30% for basket cockles collected at station G during the 1979 survey.

During the 1980 intertidal survey, again, native littlenecks were most numerous at the +1.75-foot tidal level. Butter clams, while never abundant at this station, were densest at -1.5-foot tidal height. A single *T. capax* was collected at -0.75-foot tidal height during the 1980 survey. Additionally, a single soft-shell clam was collected at the +1.75-foot tidal level. Basket cockles were concentrated at the +0.75-foot level. Station bivalve biomass estimates for commercial-size bivalves at station G were: 0.31 kg/m^2 for native littleneck clams, 0.98 kg/m^2 for butter clams, 0.09 kg/m^2 for *T. capax*, 0.03 kg/m^2 for eastern soft-shell clams, and 0.52 kg/m^2 for basket cockles. Percent composition by species was: 31.5% for native littlenecks, 36.8% for butter clams, 5.2% for *T. capax*, 5.2% for eastern soft-shells and 21.3% for basket cockles. No recruitment was observed for native littleneck clams in 1980 at this station. Butter clams and basket cockles were represented by 12.5% and 37.5% of total individuals $\leqslant$ 10 mm for each respective species.

During the 1981 intertidal survey at station G, native littleneck clams were infrequently collected. Specimens of this species were present at +0.75- and -1.5-foot tidal levels. Butter clams were most numerous at -1.5-foot tidal height. Again, a single specimen of *T. capax* was collected from -1.5-foot tidal level. Basket cockles were sparsely distributed and only collected at the +0.75-foot tidal height. Station biomass estimates for 1981 commercial bivalve data were: 0.10 kg/m^2 for native littleneck clams, 3.09 kg/m^2 for butter clams, 0.65 kg/m^2 for *T. nuttallii*, 0.11 kg/m^2 for *T. capax* and 0.44 kg/m^2 for basket cockles. Percent composition based on number of commercial-size bivalves for 1981 collections were: 8.3% for native littleneck clams, 62.5% for butter clams, 12.5% for *T. nuttallii*, 4.2% for *T. capax*

and 12.5% for basket cockles. Twenty percent of the native littleneck clams collected at station G during 1981 were ≤ 10 mm in size. No recruitment was evident for other commercial bivalve species in 1981 samples at this station.

During the period 1979, 1980 and 1981 the following average biomass data for commercial-size bivalves were collected at station G: 0.22 kg/m^2 for native littleneck clams, 2.02 kg/m^2 for butter clams, 0.43 kg/m^2 for *T. nuttallii*, 0.15 kg/m^2 for *T. capax*, 0.30 kg/m^2 for eastern soft-shell clams and 0.39 kg/m^2 for basket cockles. This station ranks third in terms of total bivalve biomass during the three-year period. Moderate recruitment of YOY native littleneck clams, butter clams and basket cockles occurred at station G during 1979, 1980 and 1981.

Station J

Intertidal bivalve samples were collected between +4.5- and –1.4-foot tidal heights at station J during 1979, 1980 and 1981 surveys. As previously discussed in the introduction section of the report, station J was established to replace station K in 1979. Station J is located on the northern side of Cattail delta (see figure 2). A beach gradient of 1:37 was measured from +5.5- to –1.5-foot tidal levels at this station (figure 12). The upper intertidal region consists of stones and rocks covering sand and pea gravel. Mussels and barnacles are abundant at the +5.0-foot tidal height at this station. A well-developed oyster bed is present in the +4.0- to +1.0-foot tidal zone. Substratum along the mid-intertidal region consists of coarse sand and scattered rocks. Below zero tidal level, eelgrass and fine gray sand compose the primary substratum. This station is sheltered from southerly wind and wave conditions, but openly exposed to weather from the north.

During the 1979 intertidal survey, native littleneck clams were concentrated at the +4.5- to +2.5-foot tidal region along the transect (table 14). Manila clams were present at +4.5-foot tidal level. Butter clams were collected from +2.5- to –1.6-foot tidal levels, but were most abundant at the +2.5-foot tidal level. Eastern soft-shell clams were collected only at the +4.5-foot tidal height. Basket cockles occurred from +2.5- to –1.6-foot tidal regions. Commercial-size bivalve biomass estimates at station J during the 1979 survey were: 0.05 kg/m^2 for native littleneck clams, 0.01 kg/m^2 for Manila clams, 0.30 kg/m^2 for butter clams and 0.02 kg/m^2 for basket cockles. Percent composition for commercial-size bivalves by species were: 44.4% for native littleneck clams, 11.1% for Manila clams, 33.4% for butter clams and 11.1% for basket cockles. Juvenile commercial bivalve species (≤ 10 mm in size) represented the following percentages of all individuals for that species: 74% for native littleneck clams, 83% for butter clams and 50% for basket cockles during the 1979 survey.

During the 1980 intertidal survey at station J, native littleneck clams were evenly distributed from the +4.5- to +1.6-foot tidal region. Several juvenile Manila clams were collected from the +4.5-foot tidal level. No butter clams were collected at station J in 1980. *Tresus capax* were present at the zero tidal level, as were the densest concentrations of basket cockles. Station biomass estimates during the 1980 survey were: 0.01 kg/m^2 for native littleneck clams, 0.57 kg/m^2 for *T. capax* and 0.09 kg/m^2 for basket cockles. Percent composition by species for commercial-size bivalves at ths station were: 60% native littlenecks, 20% *T. capax* and 29% basket cockles during the 1980 survey. Percentage data for YOY juvenile bivalves (≤ 10 mm in size) were: 70% for native littlenecks, 50% for Manila clams,

and 78% for basket cockles. These data indicate excellent recruitment for commercial bivalve species at station J, but conditions appear less than adequate for reasonable bivalve growth and survival.

During the 1981 intertidal bivalve survey, native littleneck, Manila and eastern soft-shell clams were most concentrated at the +4.5-foot tidal level. Butter clams were most abundant at the +2.5-foot level. *Tresus capax* were collected at the −1.6-foot tidal height along the transect. Basket cockles were distributed from zero tidal level to +2.5 feet intertidally. Station bivalve biomass estimates for commercial-size clams by species at station J during 1981 were: 0.09 kg/m^2 for native littlenecks, 0.52 kg/m^2 for butter clams and 0.13 kg/m^2 for basket cockles. Percent composition by species for commercial-size clams were: 33.3% for native littleneck clams, 55.6% for butter clams and 11.1% for basket cockles during the 1981 survey. Juvenile commercial clam species represented 17% of native littleneck clams, 14% of butter clams and no basket cockles at station J during 1981.

During this three-year sampling period, the average biomass for commercial-size bivalves by species at station J were: 0.05 kg/m^2 for native littleneck clams, 0.27 kg/m^2 for butter clams, 0.02 kg/m^2 for *T. capax* and 0.08 kg/m^2 for basket cockles. Station J ranks last out of seven intertidal sampling stations on the basis of overall clam biomass. Conversely, bivalve recruitment is highest at this station. Again, a consistent pattern for bivalve data (as reported at Station K previously, reference 3) indicates that conditions for bivalve growth and survival at station J are extremely poor.

Station M

This northern off-base control station was sampled only during the 1979 intertidal survey. As discussed previously in the introduction to this report, station M was established to replace station L, but did not provide representative data on commercially-significant bivalves. Station M was located approximately two kilometres north of station J (refer to figure 2). Intertidal bivalve samples were collected at station M between the +3.5- and −1.0-foot tidal levels. A beach gradient of 1:28 was measured for this intertidal range (figure 13). High intertidal substratum consisted of sand and pea gravel, with overlying scattered stones and boulders. At about a +4.0-foot tidal height, sand covered rocks and stones. Patchy eelgrass and ulvoids were present at zero tidal level and developed into a dense eelgrass bed below the −0.5-foot tidal level on the transect axis. Substratum in the eelgrass bed was fine gray sand. This station was moderately exposed to wind and wave action during most seasons.

During the 1979 intertidal survey, native littleneck and butter clams were concentrated at the +2.5-foot tidal level (table 15). A single Manila clam was also sampled at this intertidal height. Eastern soft-shell clams occurred only at the +3.5-foot tidal height. Basket cockles were densest at the zero tidal region. Station biomass estimates for commercial bivalves at station M by species were: 0.19 kg/m^2 for native littleneck clams, 0.29 kg/m^2 for butter clams, 0.07 kg/m^2 for eastern soft-shell clams and 0.85 kg/m^2 for basket cockles. Commercial-size clams were represented by the following percentages: 42.9% for native littlenecks, 14.3% for butter clams, 14.3% for eastern soft-shell clams and 28.5% for basket cockles. Only 14 commercial-size individiual bivalve specimens (representing four species)

were collected at station M during the 1979 intertidal sampling activities. Seventy-five percent of all native littleneck clams and butter clams were ≤ 10 mm in size. This station clearly was not representative of a commercially-significant clamming beach. Intertidal sampling at station M was terminated after the 1979 survey.

Intertidal bivalve surveys conducted at SUBASE Bangor during 1979, 1980 and 1981 further describe the abundance and distribution of important molluscan species along Hood Canal shoreline areas. Samples were collected from regions of commercially and recreationally significant bivalve populations to estimate density, standing crop (biomass) and recruitment of important species. Methods and locations of intertidal sampling activities during this period are comparable with previous NOSC Trident surveys.

Table 16 summarizes mean bivalve density, by species, for each station during this three-year sampling period. Species ranked in decreasing order of integrated mean densities are: *Protothaca staminea, Saxidomus giganteus, Tapes japonica, Clinocardium nuttallii, Mya arenaria, Tresus capax* and *T. nuttallii*. Stations ranked in decreasing order of total clam density, where all commercial species are combined are: D, Z, C, A, M, J and G. Butter clams and native littleneck clams were numerically dominant at all stations sampled during this period. Generally, bivalve populations were denser at southern stations (A, Z C and D) than northern stations (G, J and M). Total biomass of commercial-size clams collected during 1979, 1980 and 1981 are apportioned among all stations as follows: butter clams, 65%; native littleneck clams, 19%; basket cockles, 7%; *Tresus capax*, 4%; *Tresus nuttallii*, 2%; eastern soft-shell clams, 2% and Manila littleneck clams, 1%. Biomass of commercial-size bivalves was shared among stations, from highest to lowest values, as follows: A, C, G, D, Z, M and J.

Commercial bivalve species recruitment data collected during 1979, 1980 and 1981 surveys are summarized in table 17. Stations D and J had the highest percentages of small bivalves (≤ 10 mm), and, thus, presumably the highest recruitment potential for butter and native littleneck clams. During the 1979 survey, basket cockle recruitment was greatest at stations A, J and G. The recruitment level of YOY juvenile bivalves (≤ 10 mm) was observed to be generally independent of the adult clam population size at a given station. Stations having a gently sloping beach gradient (often delta regions) consistently exhibited greater bivalve recruitment, while they often possessed a less dense adult bivalve population. Conditions responsible for heavy settlement of juvenile bivalves are apparently unrelated to the environmental requirements necessary for sustained growth and survival.

Total mean density of commercial-size bivalves (#/square metre) and biomass (kg/square metre) are compared in table 18 from data collected during a six-year period (1976-1981). Previously utilized sampling stations (E, K, L and M) are included for comparative purposes in this summary. Again, a consistent pattern of higher bivalve density and greater biomass at southern stations is apparent. Stations A, C, Z and D continue to provide commercially significant densities and weights of clams along SUBASE Bangor. Eighty-five percent of the commercial bivalve biomass collected during the six-year period was attributable to these four stations. Stations A and C have remarkably similar overall bivalve productivity characteristics. While beach gradient and substratum composition are similar at these

Station	Size	*Protothaca Staminea*	*Tapes Japonica*	*Saxidomus giganteus*	*Tresus capax** or *T. nuttallii*	*Mya arenaria*	*Clinocardium nuttallii*
		$\overline{X}$ s	$\overline{X}$ s	$\overline{X}$ s	$\overline{X}$ s	$\overline{X}$ s	$\overline{X}$ s
A	comm	36.25(15.16)	NP	63.33(33.76)	1.67(1.44)*	1.67(2.89)	0.42(0.72)
	subc	17.08(1.91)	0.42(0.72)	83.33(5.91)	NP	NP	9.75(10.39)
Z	comm	50.83(21.2)	11.25(12.3)	21.25(6.25)	NP	0.42(0.72)	NP
	subc	28.75(15.7)	36.25(40.5)	2.50(2.17)	NP	NP	NP
C	comm	69.58(18.3)	2.50(3.31)	31.67(3.61)	NP	0.83(0.72)	NP
	subc	31.67(13.4)	6.67(8.51)	4.17(1.91)	NP	NP	NP
D	comm	32.33(6.08)	14.33(10.0)	40.00(6.24)	0.33(0.58)*	3.00(1.73)	2.67(1.53)
	subc	73.00(26.2)	13.33(11.0)	55.33(36.7)	NP	1.67(2.08)	3.67(4.62)
G	comm	8.22(5.75)	NP	14.82(6.36)	3.33(2.97)*	1.85(2.21)	4.05(1.09)
	subc	2.38(2.18)	NP	3.75(2.28)	NP	NP	2.62(2.51)
J	comm	4.03(0.87)	0.42(0.72)	3.10(3.84)	0.42(0.72)*	NP	1.20(0.08)
	subc	31.16(13.2)	1.62(0.77)	8.66(13.12)	NP	1.20(1.25)	4.91(4.41)
M**	comm	8.57	NP	2.85	NP	2.86	5.71
	subc	34.29	1.43	14.29	NP	NP	10.00

*denotes *Tresus capax.*

**station M was sampled only during 1979.

$\overline{X}$ = mean.

s = standard deviation.

comm = commercial-size individuals.

subc = subcommercial-size individuals.

Table 16. Combined mean intertidal bivalve density data (number/square metre) collected during 1979, 1980 and 1981 surveys at SUBASE Bangor.

Station/ Year	Species			
	Protothaca staminea	*Tapes japonica*	*Saxidomus giganteus*	*Clinocardium nuttallii*
A/1979	140.00 (30.43)	0.00 (0.00)[2]	120.00 (19.35)	20.00 (50.00)
1980	90.00 (16.67)	NP	30.00 (3.61)	170.00 (100.00)
1981	40.00 (14.29)	NP	20.00 (7.41)	30.00 (100.00)
Z/1979	40.00 (4.40)	70.00 (8.33)	10.00 (4.00)	NP
1980	150.00 (22.39)	90.00 (31.03)	0.00 (0.00)[2]	NP
1981	40.00 (12.90)	0.00 (0.00)[2]	20.00 (13.33)	NP
C/1979	80.00 (9.76)	70.00 (50.00)	20.00 (6.67)	NP
1980	90.00 (10.59)	10.00 (12.50)	20.00 (8.33)	NP
1981	100.00 (17.24)	NP	30.00 (10.00)	NP
D/1979	990.00 (70.71)	60.00 (35.29)	930.00 (64.14)	0.00 (0.00)[2]
1980	220.00 (23.91)	20.00 (4.76)	90.00 (14.52)	10.00 (7.69)
1981	340.00 (40.96)	0.00 (0.00)[2]	230.00 (29.11)	0.00 (0.00)[2]
G/1979	10.00 (8.33)	NP	40.00 (28.57)	10.00 (50.00)
1980	0.00 (0.00)[2]	NP	10.00 (12.50)	30.00 (37.50)
1981	10.00 (20.00)	NP	0.00 (0.00)	0.00 (0.00)[2]
J/1979	310.00 (73.81)	0.00 (0.00)[2]	190.00 (86.36)	10.00 (50.00)
1980	120.00 (70.59)	10.00 (50.00)	NP	70.00 (77.78)
1981	40.00 (17.39)	0.00 (0.00)[2]	10.00 (14.29)	0.00 (0.00)[2]
M/1979	210.00 (75.00)	0.00 (0.00)[2]	90.00 (75.00)	0.00 (0.00)[2]

NP = Not present.

[1]Number of juveniles (ie $\ell \leqslant 10$mm.), percentage of juveniles in parentheses.

[2]No recruitment evident; commercial-size individuals present.

Table 17. Commercial clam species recruitment (#/m^2) (see footnote 1).

Year	Measurement	Station A	Z	C	D	E	G	J	K	L	M
1976	D	158	78	144	NS	78	20	NS	27	5	NS
	B	5.5	5.4	4.5		3.3	1.4		0.3	0.5	
1977	D	120	94	116	NS	98	30	NS	35	50	NS
	B	5.9	5.7	10.4		4.7	4.0		0.5	6.2	
1978	D	180	76	164	NS	78	47	NS	42	NC	NS
	B	9.9	3.4	10.8		6.3	2.4		0.5		
1979	D	105	123	109	93	NS	46	9	NS	NS	20
	B	10.9	3.2	4.0	2.8		3.4	0.4			1.4
1980	D	137	85	121	96	NS	24	6	NS	NS	NS
	B	11.9	3.1	4.7	3.2		1.9	0.2			
1981	D	50	44	84	86	NS	34	10	NS	NS	NS
	B	4.2	1.9	5.0	3.3		4.4	0.7			

NS = Not sampled.
NC = No commercial-size bivalves collected.
D = density.
B = biomass.

$$\text{Density} = \frac{\Sigma \text{ individuals w/ } \ell \geqslant 30 \text{ mm}}{(\#\text{ digs containing commercial clam species})(0.1 \text{ m}^2)(1000)}$$

$$\text{Biomass} = \frac{\Sigma \text{ weights of clams w/ } \ell \geqslant \text{mm}}{(\#\text{ digs containing commercial clam species})(0.1 \text{ m}^2)(1000)}$$

Note: all commercial-size species data are combined.

Table 18. Commercial bivalve density (#/m^2) and biomass (kg/m^2) data collected at all SUBASE Bangor sampling stations during the period 1976-1981.

two stations, the proximity of station C to heavily utilized service piers demonstrates the lack of measurable adverse impact on bivalve populations along SUBASE Bangor.

We also evaluated the occurrence of commercial-size bivalves in relation to mean tidal height using data from seven stations sampled during 1979, 1980 and 1981 surveys. Commercial dig frequency results are summarized in table 19. Frequency values represent the percent of sample digs which are commercially significant (i.e. bivalve wet biomass values $\geqslant$ 277 grams/0.1 square metre of 2.77 grams/square metre) at each station. Mean tidal heights describe hypothetical intertidal levels where the densest concentrations of bivalves occur. These two statistics are useful for between-station comparisons of bivalve distribution. Stations C and Z exhibit higher commercial bivalve concentrations at upper tidal heights. The pattern is attributed to an abundance of littleneck clams which represent greater than sixty percent of commercial-size clams at these two stations. As shown in figure 4, native littleneck clams occur higher intertidally than butter clams. At stations A, D and G, butter clams represented the most common commercial-size species collected.

Oyster frequency data collected during intertidal transect sampling are presented in table 20. Oysters occurred from +6.25- to +1.0-foot tidal levels during this period. The greatest oyster densities were recorded at stations C and Z, between +4.5- and +1.75-foot tidal heights. A comprehensive oyster mapping survey performed by SUBASE Bangor fish and wildlife personnel is summarized in appendix C. These data generally agree with previous surveys (ref 3).

Eelgrass (*Zostera marina*) beds along SUBASE Bangor were described previously (ref 3). Comparable eelgrass data for the three new sampling stations, D, J and M, were taken during the 1979 survey and are summarized in table 21. Previous evaluations of eelgrass standing crop (biomass) and turion densities at SUBASE Bangor stations have described high variability in these data. Based upon previous recommendations (ref 3), eelgrass sampling was deleted from survey activities after the 1979 field efforts.

CONCLUSIONS

1. During 1979, 1980 and 1981 surveys, intertidal bivalve populations along SUBASE Bangor and adjacent shoreline regions were numerically dominated by the following species in decreasing order of abundance: native littleneck clams, butter clams, Manila littleneck clams, basket cockles, eastern soft-shell clams and horseneck clams.

2. The total bivalve biomass (kg/square metre) was distributed as follows: butter clams, native littleneck clams, basket cockles, horseneck clams, eastern soft-shell clams and Manila littleneck clams.

3. The relative importance of survey stations in terms of biomass of commercial-size bivalves, ranked in decreasing order, was: A, C, G, D, Z, M and J.

4. Recruitment during the three-year period was documented for native littleneck clams and butter clams at all stations. Recruitment levels were highest at stations D and J for these two species. Stations A and J showed significant basket cockle recruitment, especially during the 1980 survey. The recruitment of juvenile bivalves was apparently

Year	Station A	C	D	G	J	M	Z
1979	0.75 (-0.50 ±0.45)	0.63 (+1.17 ±1.13)	0.50 (+0.80 ±1.64)	0.38 (-1.10 ±0.38)	0.00 (NA)	0.00 (NA)	0.63 (+1.10 ±1.08)
1980	0.89 (-0.23 ±1.00)	0.50 (+1.44 ±1.07)	0.50 (+0.33 ±1.86)	0.13* (-1.50)*	0.13* (0.00)*	NS	0.63 (+1.16 ±1.18)
1981	0.50 (-0.25 ±0.29)	0.63 (+1.20 ±1.25)	0.50 (-0.20 ±1.79)	0.63 (-0.70 ±0.84)	0.10* (+2.00)	NS	0.25 (+1.50 ±0.00)
Mean (Standard deviation)	0.71, (0.20)	0.59, (0.08)	0.50, (0.0)	0.38, (0.25)	0.08, (0.07)	0	0.50, (0.22)

$$\text{frequency} = \frac{\Sigma \text{ commercial digs}}{\#\text{ digs containing commercial clam species}}$$

Commercial dig = dig w/ Σ weights of commercial-size individuals $>$277.0 g.

$$\text{Mean tidal height index (ft)} = \frac{\Sigma \text{ tidal heights of commercial digs}}{\#\text{ of commercial digs}}$$

*single commercial dig present.

Table 19. Commercial dig frequencies at SUBASE Bangor (1979, 1980 and 1981). (Mean tidal height ± standard deviation in parentheses).

Tidal Ht (ft)/Year	Station A	C	D	G	J	M	Z
+6.25/1979							
1980			NS				70.00 (30.00)
1981			NS				NS
+5.25/1979		0.00 (280.00)					
1980		130.00 (20.00)					50.00 (40.00)
1981		NS					NS
+5.00/1979							
1980			80.00 (0.00)				20.00 (20.00)
1981			NP				NS
+4.50/1979							45.00 (250.00)
1980					200.00 (110.00)		40.00 (30.00)
1981					90.00 (90.00)		80.00 (65.00)
+3.57/1979		50.00 (380.00)					
1980		226.67 (53.33)					
1981		260.00 (65.00)					
+3.50/1979						NP	
1980						NS	
1981						NS	
+3.00/1979		20.00 (90.00)					510.00 (455.00)
1980		260.00 (30.00)		NS			595.00 (280.00)
1981		NS		NS			450.00 (135.00)
+2.50/1979						NP	625.00 (535.00)
1980		400.00 (45.00)			20.00 (0.00)	NS	610.00 (190.00)
1981		385.00 (35.00)			100.00 (25.00)	NS	NS
+2.00/1979		40.00 (45.00)					410.00 (260.00)
1980	NP	170.00 (20.00)	NP				NS
1981	15.00 (0.00)	NS	NP				NS
+1.75/1979							
1980				NP	15.00 (0.00)		375.00 (145.00)
1981				NP	NP		290.00 (35.00)
+1.25/1979							
1980	NP						
1981	65.00 (20.00)						
+1.00/1979							
1980		15.00 (15.00)	NP				
1981		NP	NP				
	A	C	D	G	J	M	Z

NP = Not present.
NS = Not surveyed.
Frequency = mean number of individuals $\geqslant 2''$ (mean number of individuals $< 2''$ in parentheses).

Table 20. Oyster frequencies (number/square metre) present in quadrats during intertidal transect surveys at SUBASE Bangor (1979, 1980 and 1981)

Station	Distance across bed, m (percent*)	Density turions/m^2	Biomass g dry wt./m^2
D	1 (0)	910	172
	23 (33)	875	97
	46 (66)	605	147
	72 (100)	135	60
J	1 (0)	690	71
	42 (33)	525	88
	84 (66)	660	116
	126 (100)	210	71
M	1 (0)	1740	103
	19 (33)	1580	100
	60 (66)	420	78
	88 (100)	320	80

*percent distance across bed from upper (0%) side to deepest (100%) side.

Table 21. Eelgrass bed width, turion density and biomass data collected during July, 1979 at SUBASE Bangor.

independent of the adult bivalve population at a given location. These data suggest that conditions producing extensive larval release and settlement are unrelated to environmental parameters which support increased growth and survival for commercial bivalve populations adjacent to SUBASE Bangor.

5. Maximum densities of commercial-size bivalves along SUBASE Bangor shorelines occur between the +2.0- and −1.5-foot tidal levels.

6. The four southernmost sampling stations (A, Z, C and D) supported the greatest densities and biomass of commercial-size bivalves along SUBASE Bangor.

7. Intertidal data collected during 1979, 1980 and 1981 demonstrate that commercially important bivalve populations are experiencing normal recruitment, growth and survival adjacent to SUBASE Bangor. On-base construction and operational activities have not produced detectable adverse impacts on the intertidal component of the marine ecosystem.

8. Commercially harvestable oyster beds along SUBASE Bangor represent a significant resource. A resource management plan has been developed (appendix C).

HEAVY METAL SURVEYS

INTRODUCTION

Nearshore marine ecosystems respond to many natural and man-induced perturbations. Certain ecosystem component parameters can be used to detect and evaluate these conditions. Indications of abnormal conditions are measurable with varying degrees of reliability. Ecosystem components such as sediments and selected organisms have been widely used to evaluate the presence and effects of heavy metal contamination in nearshore marine environments (ref 34-51).

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SUBASE Bangor environmental surveys have been designed to provide baseline data on the presence of cadmium, chromium, copper, mercury, lead, tin and zinc in the environment and ecosystems of adjacent areas in Hood Canal. Selected heavy metals were analyzed from sediments and certain tissue samples collected during the 1980 and 1981 surveys at SUBASE Bangor (figures 14 and 15). Such heavy metal monitoring can detect anomolous levels of contaminants which may in turn indicate environmental stress.

Representative sampling areas were selected according to the following criteria. 1) maximal operational fleet activity; 2) moderate support craft activity; or 3) no pier facilities or ship-related activity (control sites). These criteria were chosen to provide a range of heavy metal content in sediments and organism tissues. A broad range of phyletic, trophic and habitat levels were also considered important in selecting specific organisms for tissue analyses. Organisms selected for 1980 heavy metal analyses were: copper rockfish, *Sebastes caurinus* Richardson, 1845, red rock crab, *Cancer productus,* Randall, 1839; bay mussel, *Mytilus edulis* Linnaeus, 1758, and sea cucumber, *Parastichopus californicus,* Stimpson, 1857. During 1981 sampling, sea cucumbers were deleted and replaced by the Pacific oyster, *Crassostrea gigas* (Thunberg, 1795). Oysters were chosen because they are 1) ubiquitously distributed along SUBASE Bangor. 2) readily collected, 3) widely used in heavy metal monitoring, and 4) commercially important. Bivalve molluscs concentrate certain heavy metals. Reference 52 recently reported the occurrence of seasonal variability of heavy metal content in *Crassostrea gigas.* However, because SUBASE Bangor monitoring surveys are conducted during mid-summer months, this species is considered a valid choice both in terms of human consumption and well-documented background studies. Geographic locations for all heavy metal sediment and organism collections are listed in appendix A. Illustrations and discussions of selected important species are provided in appendix E. Additions to the cumulative checklist are shown in appendix F.

MATERIALS AND METHODS

Three replicate sediment samples were collected from locations adjacent to SUBASE Bangor (see figure 14). Two types of sampling tecniques were used: plastic lined gravity corer and/or a diver-operated, hand-held scoop sampler. In either case, sediment from the top five centimetres (or about 100 cubic centimetres of sample volume) was retained, placed in double-labeled, zip-lock plastic bags and chilled in an ice chest on site.

Selected organisms were collected by various methods (copper rockfish by otter trawl; crabs, mussels and sea cucumbers by diving collections; oysters by intertidal collection) at locations shown in figure 15. Certain tissues were selected and size ranges established for each species used for heavy metal analyses. Rockfish liver and muscle tissues were dissected from specimens ranging from 150-215 mm in fork length. Oysters ranging from 100-150 mm in length were collected from +2.0- to +3.0-foot tidal heights at each selected station. The entire soft tissue from each oyster was used for analysis. Rock crabs ranging from 100-200 mm carapace width were collected. Crab muscle and hepatopancreas gland tissues were used in heavy metal analyses. The five muscle bands of sea cucumbers were used in the

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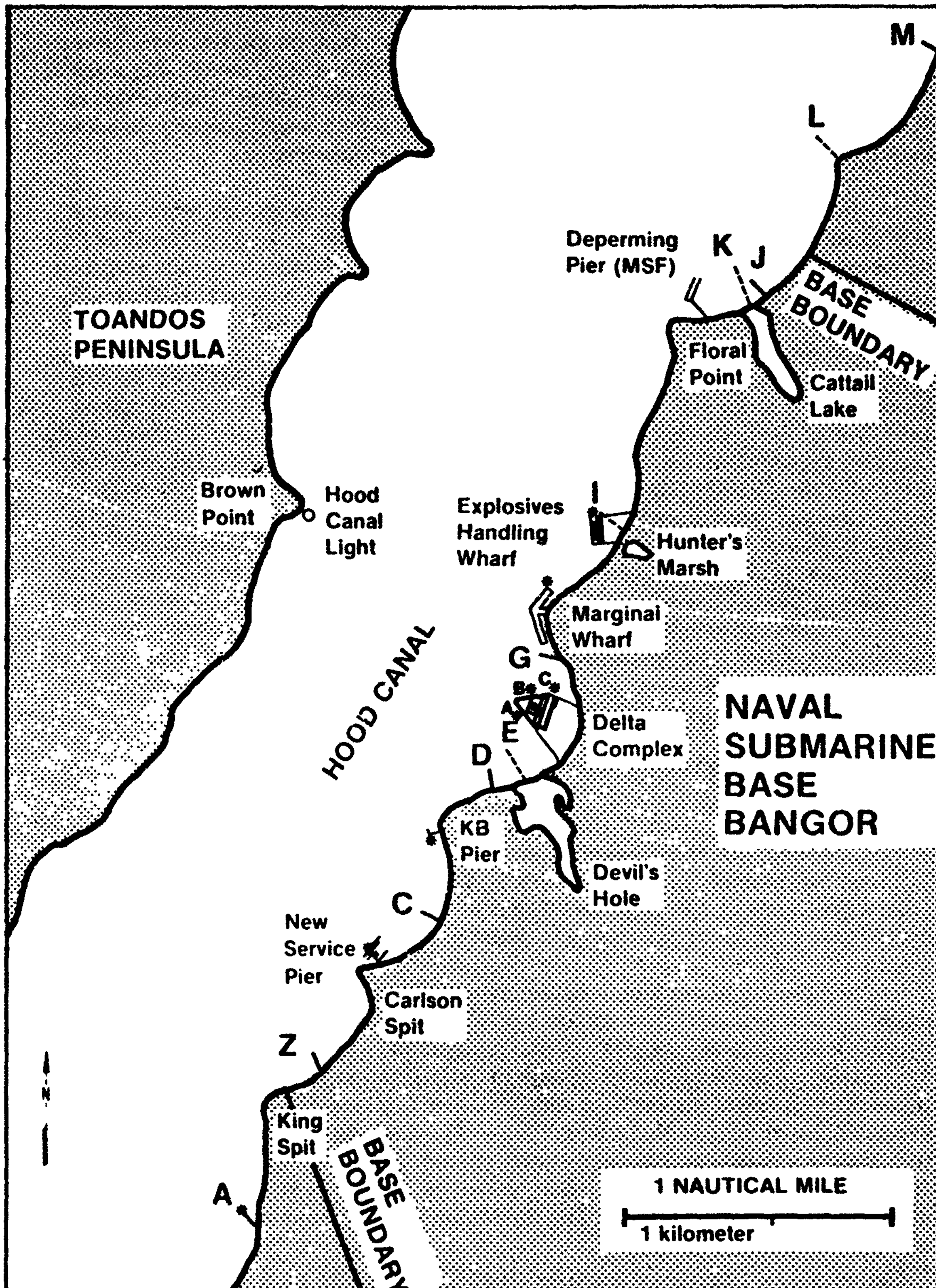

Figure 14. Sediment sample locations for heavy metal core sample collections, SUBASE Bangor. *- indicates sample collection site.

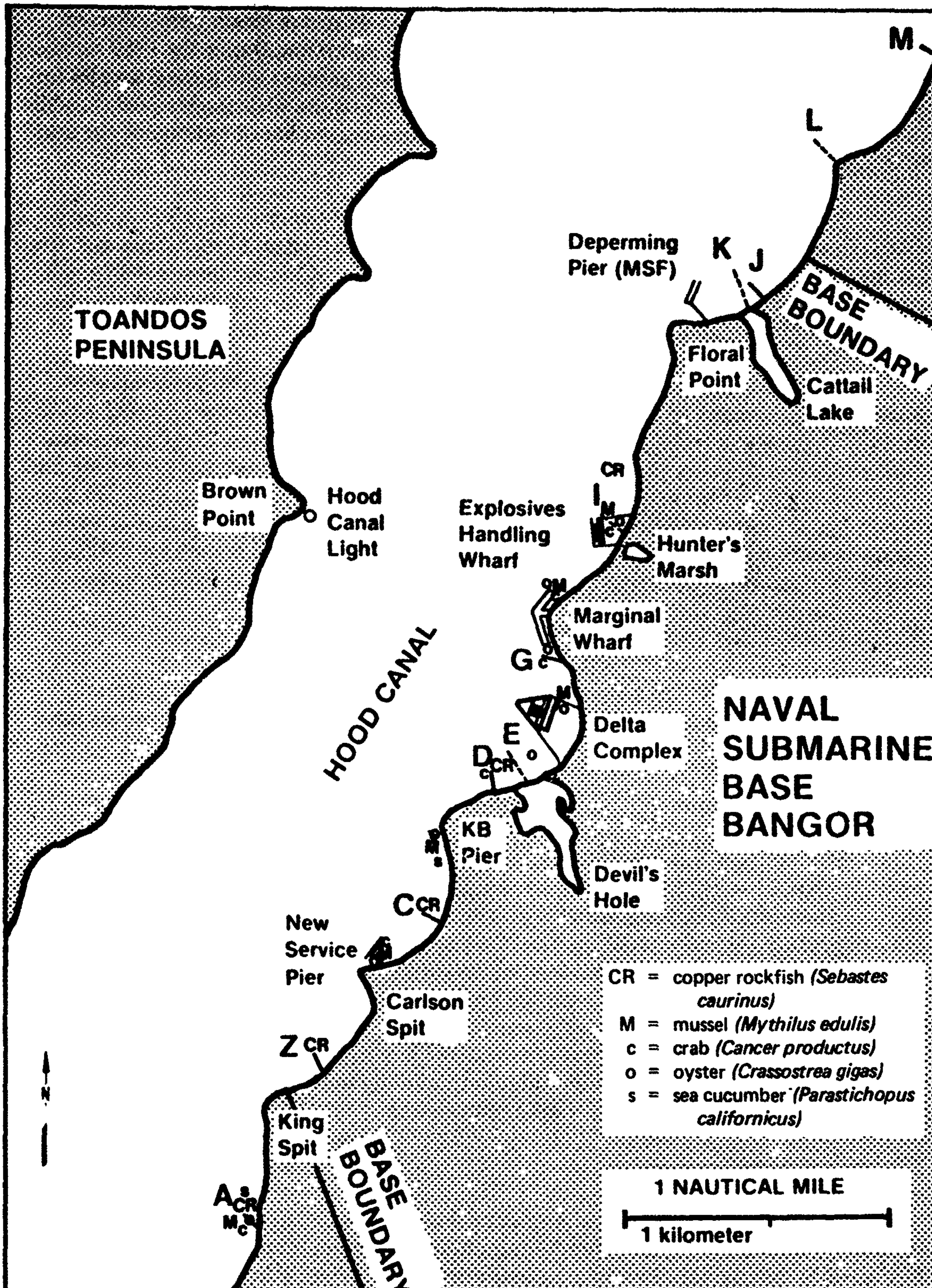

Figure 15. Organism collection locations, heavy metals.

analyses. Forty mussels (*Mytilus edulis*) ranging from 35-45 mm in length were collected from the −1.0-foot tidal level at each heavy metal sampling station. During the 1980 survey, byssal glands and adductor muscles were dissected out and grouped into pooled samples for each location. During the 1981 survey, the remaining soft tissues were also retained (in addition to byssal glands and adductor muscles). This design was developed to examine the utility of separate tissue analyses in *Mytilus edulis*.

With the exception of mussels (consisting of pooled samples), all selected heavy metals specimens were collected and analyzed separately in replicates of three from each site. During laboratory dissections, only glass, plastic and stainless steel instruments and containers were used for specimen handling to avoid contamination. Tissue and sediment samples were chilled in the field immediately after collection and frozen within six hours.

Chemical analyses were performed for 1980 and 1981 samples by Environmental Engineering Laboratory in San Diego, California. Sediment and tissue were analyzed according to Environmental Protection Agency (EPA) procedures. Hot nitric acid reflux was used during digestion. Mercury samples were analyzed using a cold vapor technique (EPA Method 245.5). Heavy metal analyses were performed using atomic absorption techniques. Tin (Sn) was deleted from the analytical protocol after 1980 samples revealed extremely low levels (below detection limits) in most cases. Heavy metal data are reported in mg/kg dry weight, except for mercury, which is reported in mg/kg wet tissue weight and percent moisture.

RESULTS AND DISCUSSION

The results of heavy metal surveys are presented and discussed in two parts: sediments and tissues. The detection limits for specific metals in sediments and tissues are listed in table 22.

Sediments

The results of sediment heavy metal analyses for samples collected during 1980 and 1981 are shown in table 23. The data are variable, but the presence of military operations and a characteristic "ship's signature" is evident from samples collected near stations KB and MW, particularly for copper, lead and zinc. For copper, mercury and lead, values vary greatly between 1980 and 1981. Sediments adjacent to northern Marginal Wharf were intensively sampled during the 1981 survey to validate high mercury levels seen in 1980. The 1981 data, however, show values well within the average ranges for other sampling sites, including the control station, A. Apparently, heavy metal content within the sediments can fluctuate widely at a single location. Therefore, considerable background data are probably required to establish a reasonable baseline for valid comparisons.

Tissues

Certain organisms, primarily bivalve molluscs, retain metals in their tissues at concentrations oftentimes several orders of magnitude greater than levels in surrounding waters. Furthermore, certain organisms may be useful biological monitors for specific heavy metals. The results of heavy metal analyses for selected tissues in several common Hood Canal organisms are presented and discussed in this section.

Metal	Sample Type: Organism Tissues	Sample Type: Sediments
Cd	0.2-1.5*	0.3-0.5*
Cr	1.0	NA
Cu	NA	NA
Hg	0.01-0.02*	0.02
Pb	0.5-1.5*	1.0
Sn	10.0-40.0*	3.0-5.0*
Zn	NA	NA

NA = Not available.

*Varies with sample weight.

Table 22. Heavy metal detection limits (mg/kg) dry weight except Hg (wet weight).

Metal/ Year	Station: A(control)	NSP	KB	DC-A	DC-B	DC-C	MW	EHW
Cd/1980	BDL	BDL	2.32 ± 2.13	BDL	BDL	0.55 ± 0.77*	2.37 ±0.60	1.18 ± 1.72*
1981	BDL	1.50 ± 1.10	3.58 ± 1.24	0.55 ± 0.17*	NS	0.61 ± 0.33*	1.39 ±0.74	0.83 ±0.58
Cr/1980	18.80 ± 0.45	21.33 ±4.13	24.67 ±9.03	30.89 ± 7.32	29.50 ±7.64	23.78 ± 2.82	30.00 ±7.55	22.11 ±3.10
1981	52.67 ± 38.81	64.83 ± 6.11	70.17 ± 15.20	65.44 ± 5.75	NS	77.56 ± 39.01	69.11 ±56.83	83.00 ±4.36
Cu/1980	7.96 ± 0.69	9.62 ± 3.09	54.17 ±40.75	14.87 ± 5.60	16.33 ±4.76	12.33 ± 2.69	331.67 ±445.26	14.74 ±3.54
1981	13.33 ± 9.29	12.17 ± 2.56	165.33 ± 218.94	10.89 ± 2.61	NS	13.00 ± 11.80	31.56 ±18.39	15.33 ±0.58
Hg/1980	1.84 ± 1.14	4.33 ± 1.85	26 67 ± 11.81	4.63 ± 3.40	7.78 ±3.69	8.20 ± 3.76	220.67 ±19.09	4.67 ±2.49
1981	0.17 ± 0.09	0.24 ± 0.10	0.21 ±0.14	0.36 ± 0.06	NS	0.27 ± 0.19*	0.39 ±0.23	0.24 ±0.20*
Pb/1980	8.26 ± 1.32	8.71 ± 4.89	39.33 ± 23.04	7.36 ± 0.86	9.55 ±2.93	10.20 ± 4.04	234.00 ±324.08	8.41 ±1.45
1981	BDL	BDL	164.00 ± 163.00	1.63 ± 2.20*	NS	BDL	15.38 ±10.73	BDL
Sn/1980	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1981	NS	NS	NS	NS	NS	NS	NS	NS
Zn/1980	34.40 ± 3.21	44.83 ± 17.59	1999.50 ± 4155.28	40.89 ± 4.28	47.17 ±11.07	47.44 ± 6.88	260.67 ±65.39	56.44 ±16.31
1981	33.67 ± 3.79	44.17 ± 7.70	585.83 ± 749.80	36.33 ± 3.84	NS	37.33 ± 3.12	129.89 ±93.92	50.33 ±1.53
%Moisture (1981 only)	25.23 ± 2.74	26.93 ± 4.34	34.13 ± 4.46	26.67 ± 6.61	NS	21.50 ± 4.32	43.18 ±7 04	21.07 ±6.07

NS = Not surveyed.

BDL = All sample data below detection limits.

*Data reported at BDL (eg <0.5) included in calculations (eg <0.5 →0.49), other sample data treated normally.

Table 23. SUBASE Bangor heavy metal sediment data (1980 and 1981). Values in mg/kg dry weight (mean ± standard deviation). Mercury (Hg) values in mg/kg wet weight.

Copper Rockfish

Copper rockfish muscle and liver tissue heavy metal data are presented in tables 24 and 25. Except for station Z, metal levels were relatively consistent for all stations. At station Z, copper, lead and zinc values were elevated, especially in liver tissue, relative to other stations. Rockfish samples were analyzed for heavy metal content at station Z only for samples collected during the 1981 survey. The average length of rockfish specimens at station Z was 150 mm, whereas the average at other stations approached 200 mm. This size difference may reflect biotic factors which, in turn, may affect heavy metal levels in tissues. The combined station data indicate that copper rockfish concentrate zinc in liver tissue at concentrations above muscle and sediment levels. Copper levels in rockfish liver tissue was similar to respective copper concentrations in sediment samples. The lead content was significantly elevated in both liver and muscle tissues for rockfish collected in 1981. Unusually low lead levels measured for 1980 specimens may account for this discrepancy.

Rock Crabs

Rock crab tissue heavy metal data are listed in tables 26 and 27. Heavy metal values are relatively consistent between stations. Rock crabs may concentrate cadmium in the hepatopancreas gland. Additionally, hepatopancreas gland cadmium levels are considerably higher in 1981 samples than those collected in 1980. Copper, lead and zinc levels are greater in both crab muscle and hepatopancreas glands than in sediments collected from equivalent locations. Chromium and mercury levels are low in both tissue types. Again, as with rockfish, lead values were significantly higher for both kinds of crab tissues sampled in 1981 collections than for 1980.

Oysters

Oyster heavy metal tissue data are listed in table 28. Oysters were collected for heavy metal analyses only during the 1981 survey. Station A (control) demonstrates typically low tissue levels for all heavy metals. Marginal Wharf represents the most heavily impacted site due to its operational status during the last two decades. Copper values were similar for oyster tissues and sediments collected at Marginal Wharf. These preliminary data indicate that oysters collected from six SUBASE Bangor intertidal regions accumulate some heavy metals in their soft tissues. However, the bioconcentration effects do not exceed one order of magnitude when compared with equivalent location sediment data.

Mussels

Mussel tissue heavy metal data are presented in tables 29, 30 and 31. The "general" tissue values shown in table 29 were collected during the 1981 survey and analyzed to evaluate the validity of separate tissue dissections for mussels. The "general" tissue consists of all mussel soft parts minus the adductor muscle and byssal gland tissue which are listed in tables 30 and 31, respectively. An analysis of variance performed on these data indicated that no significantly different heavy metal information was obtained using separate mussel tissues. Therefore, in all subsequent surveys the entire soft parts of pooled (10 individuals) *Mytilus edulis* samples will be analyzed for each station. Surprisingly, the highest mercury levels present in mussel tissues were observed at station A, the control station. Copper, lead

Metal/Year	Station A(control)	Z	C	D-E[1]	I
Cd/1980	BDL	NS	BDL	BDL	BDL
1981	BDL	BDL	BDL	BDL	BDL
Cr/1980	1.67 ± 0.15	NS	1.05 ± 0.21	1.0	1.13 ± 0.06
1981	BDL	BDL	BDL	BDL	BDL
Cu/1980	3.30 ± 1.01	NS	2.85 ± 0.92	3.0	2.77 ± 0.32
1981	3.43 ± 2.80	7.40 ± 5.72	3.33 ± 2.02	2.50 ± 0.69	3.00 ± 1.87
Hg/1980[2]	0.17 ± 0.03[3]	NS	0.22 ± 0.08	0.31	0.33 ± 0.05
1981	0.87 ± 0.28	0.34 ± 0.04	0.38 ± 0.51	0.17 ± 0.03	0.11 ± 0.02
Pb/1980	1.80 ± 0.36	NS	1.35 ± 1.21*	BDL	2.07 ± 0.29
1981	27.67 ± 19.66	35.33 ± 12.70	26.67 ± 18.50	25.33 ± 6.51	22.33 ± 9.71
Sn/1980	BDL	NS	BDL	BDL	BDL
1981	NS	NS	NS	NS	NS
Zn/1980	41.67 ± 4.73	NS	29.00 ± 8.49	25.0	26.67 ± 2.89
1981	42.33 ± 20.03	56.67 ± 18.01	31.33 ± 7.09	30.00 ± 5.00	32.00 ± 5.20
% Moisture (1981 only)	78.93 ± 0.32	78.40 ± 0.78	79.13 ± 0.76	78.37 ± 0.15	77.80 ± 0.44

NS = Not surveyed.
BDL = All sample data below detection limits.
*Individual data reported as <x (eg <0.5) included in calculations (eg <0.5 → 0.49), other sample data treated normally.

[1] n = 1 (1980 only).
[2] Tissue type not provided (except: [3]).
[3] Muscle tissue data provided only, liver tissue data not provided.

Table 24. Rockfish muscle tissue heavy metal data mg/kg dry weight except Hg, wet weight, (mean ± standard deviation).

Metal/Year	A(control)	Z	C	D--E[1]	I
			Station		
Cd/1980	BDL	NS	BDL	1.7	1.50 ± 0.10
1981	BDL	BDL	BDL	BDL	BDL
Cr/1980	16.43 ± 22.14	NS	BDL	1.3	BDL
1981	BDL	BDL	BDL	BDL	BDL
Cu/1980	15.67 ± 1.53	NS	17.00 ± 4.24	12.0	12.67 ± 2.52
1981	26.00 ± 15.59	42.00 ± 11.53	21.67 ± 10.50	16.33 ± 3.06	25.33 ± 2.89
Hg/1980[2]	NA[3]	NS	0.22 ± 0.08	0.31	0.33 ± 0.05
1981	0.11 ± 0.16*	0.95 ± 0.02	BDL	0.46 ± 0.04*	0.09 ± 0.14*
Pb/1980	BDL	NS	BDL	BDL	BDL
1981	85.00 ± 11.53	130.33 ± 64.08	115.67 ± 64.42	95.67 ± 33.32	74.00 ± 17.78
Sn/1980	BDL	NS	BDL	BDL	BDL
1981	NS	NS	NS	NS	NS
Zn/1980	225.33 ± 32.08	NS	132.50 ± 0.71	170.0	151.67 ± 57.71
1981	159.33 ± 5.03	240.33 ± 46.82	178.67 ± 24.01	157.67 ± 19.35	170.33 ± 23.01
% Moisture (1981 only)	65.12 ± 7.41	65.60 ± 1.48	68.23 ± 3.60	67.37 ± 3.36	65.20 ± 2.38

NS = Not surveyed.
BDL = All sample data below detection limits.
*Individual data reported as $<x$ (eg <0.5) included in calculations (eg $<0.5 \rightarrow 0.49$), other sample data treated normally.

[1] n = 1 (1980 only).
[2] Tissue type not provided (except:[3]).
[3] Muscle tissue data provided only, liver tissue data not provided.

Table 25. Rockfish liver tissue heavy metal data mg/kg dry weight except Hg, wet weight, (mean ± standard deviation).

Metal/Year	A(control)	NSP	KB	Station D-E	G	MW	EHW
Cd/1980	1.83 ± 2.75*	BDL	0.77 ± 0.21	BDL	1.27 ± 0.97	0.63 ± 0.45	0.80 ± 0.41
1981	BDL	BDL	BDL	BDL	BDL	1.17 ± 0.25	3.60 ± 2.46
Cr/1980	0.90 ± 0.26	0.90 ± 0.53*	1.37 ± 0.60	0.97 ± 0.67*	1.06 ± 0.78*	0.56 ± 0.06*	1.00 ± 0.18
1981	BDL	1.27 ± 0.64*	1.67 ± 1.33*	3.10 ± 3.81*	1.57 ± 0.59*	BDL	BDL
Cu/1980	72.33 ± 67.40	27.00 ± 4.00	14.70 ± 5.80	22.00 ± 5.66	51.00 ± 32.08	10.70 ± 2.91	16.25 ± 4.72
1981	23.00 ± 7.00	17.67 ± 4.51	24.67 ± 3.06	26.33 ± 7.09	21.33 ± 7.64	23.33 ± 11.93	36.00 ± 9.64
Hg/1980	0.24 ± 0.06	0.19 ± 0.06	0.33 ± 0.25	0.25 ± 0.03	0.39 ± 0.06	0.19 ± 0.02	0.17 ± 0.14
1981	0.15 ± 0.24*	1.05 ± 0.21	0.22 ± 0.08	0.46 ± 0.16	0.11 ± 0.05	0.33 ± 0.15	0.52 ± 0.07
Pb/1980	BDL	0.56 ± 0.12*	BDL	0.61 ± 0.30*	2.60 ± 2.17	BDL	BDL
1981	17.67 ± 8.96	26.00 ± 7.81	27.33 ± 10.07	28.00 ± 5.00	27.00 ± 20.66	31.67 ± 6.66	41.00 ± 4.36
Sn/1980	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1981	NS	NS	NS	NS	NS	NS	NS
Zn/1980	406.33 ± 55.90	339.00 ± 35.04	405.00 ± 28.69	322.17 ± 35.86	391.00 ± 42.33	378.00 ± 15.72	321.50 ± 62.68
1981	342.67 ± 48.18	341.00 ± 65.64	405.67 ± 17.93	413.67 ± 11.37	348.00 ± 26.15	370.67 ± 89.02	334.33 ± 20.98
% Moisture (1981 only)	75.83 ± 2.23	76.63 ± 0.64	77.90 ± 0.00	78.60 ± 4.93	81.57 ± 6.34	77.97 ± 0.67	77.60 ± 1.65

NS = Not surveyed.

BDL = All sample data below detection limits.

*Individual data reported as $<x$ (eg <0.5) included in calculations (eg $<0.5 \rightarrow 0.49$); other sample data treated normally.

Table 26. Crab muscle tissue heavy metal data in mg/kg dry weight except Hg, wet weight, (mean ± standard deviation).

Metal/Year	A(control)	NSP	KB	D-E	G	MW	EHW
				Station			
Cd/1980	13.33 ± 1.53	19.33 ±7.77	10.53 ±1.75	21.00 ±5.29	12.67 ±1.53	13.37 ±6.07	13.25 ±2.63
1981	43.33 ± 18.90	74.67 ± 21.94	99.67 ±8.08	44.00 ±19.31	68.33 ±8.50	42.00 ±12.49	50.00 ±4.36
Cr/1980	BDL	1.46± 0.55*	BDL	3.20 ± 2.51	BDL	BDL	BDL
1981	BDL	1.23± 0.31*	3.07± 1.59	4.10± 1.71	2.30 ± 1.31*	2.73± 1.25	2.30± 2.34
Cu/1980	34.33 ± 13.65	52.33 ± 9.29	18.33 ±5.13	53.00 ±27.22	35.67 ±8.02	41.33 ±19.86	19.75 ±2.36
1981	29.33± 5.13	34.00 ± 16.70	39.67 ± 21.39	32.00 ±27.73	18.33 ±6.35	23.00 ±5.29	34.33 ±7.37
Hg/1980	0.27± 0.16	0.12± 0.03	0.07± 0.02	0.13± 0.10*	0.11 ± 0.07	0.35 ± 0.07	0.16± 0.29*
1981	0.07± 0.10*	0.37± 0.07	0.10± 0.09*	0.14 ± 0.09	BDL	0.08 ±0.04	0.26 ±0.12
Pb/1980	BDL	BDL	BDL	2.86± 1.24*	1.10 ± 0.35*	BDL	BDL
1981	18.67± 2.31	27.00± 13.23	26.33± 8.50	25.97± 23.55	68.33 ± 37.53	29.00± 19.29	37.33± 4.16
Sn/1980	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1981	NS	NS	NS	NS	NS	NS	NS
Zn/1980	193.33± 15.37	175.67± 2.31	209.33± 47.65	206.67± 30.24	201.33 ± 46.00	248.00± 91.76	225.25± 31.82
1981	157.33± 51.29	301.00± 120.38	281.67± 106.40	269.00± 100.95	492.67 ± 317.31	271.67± 27.54	226.00± 33.72
% Moisture (1981 only)	71.70± 1.67	73.53± 4.63	72.57± 5.15	75.30± 6.94	76.87 ± 8.11	76.07± 5.58	77.73± 3.62

NS = Not surveyed.

BDL = All sample data below detection limits.

*Individual data reported as $<x$ (eg <0.5) included in calculations (eg $<0.5 \rightarrow 0.49$); other sample data treated normally.

Table 27. Crab hepatopancreas tissue heavy metal data mg/kg dry weight except Hg, wet weight, (mean ± standard deviation).

Metal	A(control)	NSP	DC	D-E	MW	EHW
			Station			
Cd	9.43 ± 3.50	12.23 ± 4.29	12.67 ± 2.31	19.00 ± 4.00	18.67 ± 0.58	15.53 ± 7.71
Cr	0.76 ± 1.16*	1.73 ± 0.80*	BDL	BDL	BDL	BDL
Cu	27.67 ± 4.93	81.33 ± 19.35	81.00 ± 28.16	106.33 ± 35.50	256.00 ± 88.71	181.00 ± 109.05
Hg	0.10 ± 0.07	BDL	BDL	0.14 ± 0.11*	0.03 ± 0.03*	BDL
Pb	9.43 ± 5.13	20.67 ± 4.73	23.00 ± 12.53	11.30 ± 5.74	39.67 ± 15.04	14.00 ± 4.00
Sn	NS	NS	NS	NS	NS	NS
Zn	572.33 ± 198.53	1520.67 ± 720.60	956.67 ± 337.51	1413.67 ± 340.08	2363.33 ± 715.95	2247.67 ± 1058.77
% Moisture	73.80 ± 3.26	73.93 ± 1.02	80.40 ± 2.10	75.57 ± 0.76	82.00 ± 1.48	79.23 ± 3.02

NS = Not surveyed.

BDL = All sample data below detection limits.

*Individual data reported as $<x$ (eg <0.5) included in calculations (eg $<0.5 \rightarrow 0.49$); other sample data treated normally.

Table 28. Oyster tissue heavy metal data (1981 only) mg/kg dry weight except Hg, wet weight, (mean ± standard deviation).

Metal	Station A(control)	NSP	KB	DC	MW	EHW
Cd	9.8	3.8	5.5	12.0	4.9	11.0
Cr	<1.0	2.5	<1.0	<1.0	<1.0	1.1
Cu	11.0	11.0	18.0	8.6	11.0	14.0
Hg	0.53	0.18	0.07	0.54	0.51	0.26
Pb	49.0	28.0	31.0	60.0	39.0	35.0
Sn	NS	NS	NS	NS	NS	NS
Zn	153.0	120.0	159.0	196.0	146.0	158.0
% Moisture	80.3	80.7	82.3	83.3	82.7	83.3

NS = Not Surveyed.

Table 29. *Mytilus* general tissue heavy metal data (1981 only) mg/kg dry weight except Hg, wet weight.

Metal/Year	Station A(control)	NSP	KB	DC	MW	EHW
Cd/1980	3.3	4.1	3.7	2.5	3.3	2.2
1981	<1.0	<1.0	<1.0	3.0	1.9	5.4
Cr/1980	<2.0	<1.5	<1.5	<1.5	<1.5	<1.5
1981	3.5	<1.0	<1.0	<1.0	<1.0	<1.0
Cu/1980	22.0	18.0	17.0	14.0	14.0	9.6
1981	6.9	7.7	16.0	3.0	7.7	5.4
Hg/1980	1.37	0.05	0.38	0.09	<0.02	0.17
1981	0.60	0.13	0.31	0.77	0.24	0.21
Pb/1980	10.0	4.1	<1.5	<1.5	<1.5	<1.0
1981	41.0	73.0	123.0	40.0	46.0	54.0
Sn/1980	<40 0	<40.0	<40.0	<40.0	<40.0	<30.0
1981	NS	NS	NS	NS	NS	NS
Zn/1980	199.0	243.0	207.0	283.0	158.0	103.0
1981	149.0	172.0	207.0	165.0	132.0	149.0
% Moisture (1981 only)	78.1	78.0	76.7	78.5	78.4	77.5

NS = Not surveyed.

Table 30. *Mytilus* muscle tissue heavy metal data (1980-1981) mg/kg dry weight except Hg, wet weight.

Metal/Year	Station A(control)	NSP	KB	DC	MW	EHW
Cd/1980	6.7	5.5	7.0	5.5	6.4	4.7
1981	5.4	6.0	2.6	3.6	1.1	4.3
Cr/1980	7.4	11.0	7.4	<0.6	3.5	3.6
1981	6.9	3.6	<1.0	<1.0	<1.0	<1.0
Cu/1980	25.0	23.0	20.0	15.0	28.0	14.0
1981	6.9	9.6	10.0	7.1	6.7	7.5
Hg/1980	1.15	0.41	0.39	0.44	0.66	0.22
1981	0.71	0.08	0.24	0.62	0.43	0.39
Pb/1980	7.4	4.6	18.0	7.1	2.9	5.2
1981	25.0	24.0	37.0	29.0	27.0	25.0
Sn/1980	<30.0	<20.0	<20.0	<20.0	<20.0	<10.0
1981	NS	NS	NS	NS	NS	NS
Zn/1980	185.00	180.0	228.0	200.0	172.0	217.0
1981	141.0	120.0	116.0	102.0	106.0	90.0
% Moisture (1981 only)	76.8	77.7	76.9	78.4	79.4	79.8

NS = Not surveyed.

Table 31. *Mytilus* byssal gland tissue heavy metal data (1980-1981) mg/kg dry weight except Hg, wet weight.

and zinc levels were highest in mussle samples collected from Marginal Wharf, KB Pier and the Explosives Handling Wharf. Mussles appear to concentrate lead and zinc in their tissues at levels above those of nearby sediments.

Sea Cucumbers

Sea cucumber heavy metal tissue data are listed in table 32. Sea cucumbers were collected only from stations A and KB during the 1980 survey. Sea cucumbers are detritus feeders. The results do not indicate significant differences in sea cucumber metal content between stations A (control) and KB, with the exception of lead. Sea cucumbers are not recommended for continued metal monitoring during future SUBASE Bangor surveys.

Overview

Heavy metal data were further summarized by combining all stations by sample type for an indication of average Hood Canal values along SUBASE Bangor. Mean data for each selected heavy metal and for each category of sample are listed in table 33. High variability in sediment data is indicated by the large standard deviations about the means. Elevated mercury levels observed in 1980 sediment samples were not repeated in 1981 sample data. Data presented in table 33 agree closely with similar heavy metal data recently reported from central and southern Puget Sound (ref 44, see table 34). Reference 43 (p 48-51) provides definitions pertinent to this discussion. Bioconcentrator organisms selectively accumulate and concentrate trace metals by sequestering them into certain organs or tissues such as skin, bone, hepatopancreas, liver or muscle. While toxic substances are concentrated in very high quantities in specific organs, these bioconcentrator biota are not adversely affected. An example of bioconcentration occurs with oysters in certain environments which sequester high concentrations of copper, causing "greening" of tissues. One measurement of the relationship between the level of a trace element in the organism compared with the level in the surrounding environment is the concentration ratio (ref 43). Certain concentration ratios of trace metals in edible tissues of marine and freshwater invertebrates and fish are shown in table 35. Applying these ratios to specific organisms or locations should be performed with caution, however, as water trace metal data are often used as background environmental values. As stated earlier, water heavy metal data are seldom reliable indices to actual organism concentrations, especially in an environment like Hood Canal, which experiences tremendous flushing with tidal exchange. Selected biota analyzed for heavy metal content along SUBASE Bangor appear to be well within the recommended guidelines for human consumption. Bioconcentration, as defined in reference 43, is apparent in the following species/tissues when compared with heavy metal sediment levels: *Cancer productus* (crab) hepatopancreas gland for cadmium; *Crassostrea gigas* (oyster) for cadmium; *Mytilus edulis* (mussel) for cadmium; oyster for copper; oyster and mussel for lead; *Sebastes caurinus* (copper rockfish) liver for lead; and oyster for zinc. These summary data are useful to initiate baseline heavy values for sediment and selected tissue levels along SUBASE Bangor marine environments.

During future surveys, two additional types of heavy metal samples are recommended: 1) the commercially important butter clam, *Saxidomus giganteus*, a filter feeding, common intertidal species and *Macoma inquinata*, a deposit-feeding, common non-commercial intertidal bivalve, and 2) sediment samples from intertidal regions collected adjacent to samples of the above clams. These additional samples are considered important to provide a

	Station	
Metal/Year	A(control)	KB
Cd/1980	BDL	1.75 ± 0.07
Cr/1980	1.43 ± 0.22	1.75 ± 0.92
Cu/1980	3.73 ± 1.02	9.35 ± 2.33
Hg/1980	0.03 ± 0.03*	0.31 ± 0.30
Pb/1980	1.02 ± 0.42*	5.30 ± 0.42
Sn/1980	BDL	BDL
Zn/1980	118.50 ± 4.36	147.50 ± 17.68

BDL = All sample data below detaction limits.

*Individual data reported as <x (eg <0.05) included in calculations (eg <0.5 → 0.49); other sample data treated normally.

Table 32. *Parastichopus californicus* (sea cucumber) muscle tissue heavy metal data (1980 only). Values in mg/kg dry weight except Hg, wet weight (mean ± standard deviation).

Sample Type	(n)	Year	Cd	Cr	Cu	Hg**	Pb	Sn	Zn	% Moisture
			Metal							
Sediment	(53)	1980	0.85±1.25*	25.06±6.71	35.72±115.46	19.84±4[illegible].98[1]	24.95±82.86	BDL	279.36±1431.08[2]	NS
	(45)	1981	1.28±1.20*	69.47±31.96	36.67±90.57	0.29±0.17*	25.69±77.99*	NS	130.31±315.37	29.50±9.47
Crab	(25)	1980	0.84±0.97*	0.97±0.50*	28.97±29.68	0.25±0.12	0.85±0.95*	BDL	359.08±51.98	NS
Muscle	(21)	1981	1.32±1.24*	1.47±1.50*	24.62±8.46	0.41±0.33*	28.00±11.28	NS	365.14±50.66	77.99±3.23
Crab	(22)	1980	14.71±5.14	1.32±1.13*	35.64±17.95	0.17±0.20*	1.28±0.79*	BDL	209.27±44.10	NS
Hepatopan.	(21)	1981	61.71±23.08	2.38±1.58*	30.10±14.60	0.15±14.60	33.23±22.43	NS	285.62±153.82	74.82±5.05
Oyster	(NS)	1980	NS	NS	NS	NS	NS	NS	NS	NS
Tissue	(18)	1981	14.59±5.10	1.11±0.49*	122.22±92.72	0.05±0.07*	16.68±10.48	NS	1512.39±848.70	77.49±3.77
Rockfish	(9)	1980	BDL	1.28±0.32	2.99±0.67	0.25±0.08[3]	1.64±0.71*	BDL	32.00±8.41	NS
Muscle	(15)	1981	BDL	BDL	3.93±3.21	0.38±0.36	27.47±12.91	NS	38.47±15.01	78.01±2.05
Rockfish	(9)	1980	1.52±0.09*	6.21±13.47*	14.56±2.92	0.25±0.08[3]	BDL	BDL	167.00±56.58	NS
Liver	(15)	1981	BDL	BDL	26.27±12.29	0.24±0.38*	100.13±43.00	NS	181.27±39.06	66.31±3.76
Mytilus	(6)	1980	3.18±0.72	BDL	15.77±4.23	0.35±0.52*	3.25±3.50*	BDL	198.83±63.17	NS
Muscle	(6)	1981	2.17±1.79*	1.33±1.06*	7.78±4.40	0.38±0.25	62.83±31.88	NS	162.33±25.97	77.87±0.67
Mytilus	(6)	1980	5.97±0.88	5.58±3.72*	20.83±5.56	0.55±0.33	7.53±5.39	BDL	197.00±22.04	NS
Byssal Gl.	(6)	1981	3.83±1.81	2.35±2.48	7.97±1.45	0.41±0.23	27.83±4.83	NS	112.50±17.55	78.17±1.26
Mytilus	(NS)	1980	NS	NS	NS	NS	NS	NS	NS	NS
Tissue	(6)	1981	7.83±3.51	1.20±0.64	12.27±3.29	0.35±0.24	40.33±12.09	NS	155.33±24.58	82.10±1.30
Parastichopus	(6)	1980	0.91±0.65*	1.88±1.30	5.97±2.82	0.12±0.20	2.45±2.24*	BDL	128.17±17.27	NS
Muscle	(NS)	1981	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not surveyed.
BDL = All sample data below detection limits.
*Individual data reported as < x (ie below detection limit; eg < 0.5) included in mean & sd calculations (eg < 0.5 → 0.49), other data treated normally.
**Hg data reported in mg/kg wet weight

[1] n = 54 (based on inclusion of 3 highly suspect Hg samples from MW)
[2] mean ± sd → 83.37 ± 111.05 (n = 52) if sample with reported value of 10,471 mg/kg Zn is detected.
[3] tissue type not specified.

Table 33. A summary of heavy metal content in sediment and tissues collected at SUBASE Bangor (1980 and 1981) in mg/kg dry weight (except Hg, wet weight).

	Mean Concentration (ppm)	Minimum Concentration (ppm)	Maximum Concentration (ppm)	Coefficient of variation (%)
Metal:				
Arsenic	27.56	0.00	472.00	319
Lead	103.84	7.93	793.00	148
Copper	116.59	10.20	1602.00	210
Zinc	153.99	23.20	1720.00	170
Mercury	0.40	0.02	1.38	95
Selenium	29.47	9.30	113.00	72
Cadmium	7.27	3.08	18.30	43
Chromium	41.87	20.90	71.50	33

Table 34. Sediment heavy metal data listed in reference 44, for comparison with SUBASE Bangor data. Statistics are for 41 Puget Sound sampling stations (MESA Project).

	Marine		Freshwater	
	Invertebrates	Fish	Invertebrates	Fish
Antimony	0.005	0.04	0.01	0.001
Arsenic	0.333	0.333	0.333	0.333
Beryllium	0.2	0.2	0.01	0.002
Cadmium	50.0	3.0	2.0	0.2
Chromium	2.0	0.4	0.04	0.04
Cobalt	1.0	0.1	0.2	0.02
Copper	1.67	0.667	1.0	0.2
Lead	1.0	0.3	0.1	0.3
Mercury	33.3	1.67	100.0	1.0
Nickel	0.25	0.1	0.1	0.1
Selenium	1.0	4.0	0.167	0.167
Tin	1.0	3.0	1.0	3.0
Vanadium	0.05	0.01	3.0	0.01

Source: Adapted from reference 52.

Table 35. Data listed for comparison with SUBASE BANGOR data: concentration ratios of trace metals in edible tissues of invertebrates and fish (X 1,000 ppm) (ref 43)

more comprehensive evaluation of intertidal metal burdens along SUBASE Bangor. Future surveys will include these data and serve to monitor key elements in the Hood Canal ecosystem.

CONCLUSIONS

1. Heavy metal data collected during 1980 and 1981 indicate that levels present along SUBASE Bangor are similar to other areas of Puget Sound.

2. Sediment data are highly variable with respect to heavy metal content at a given location.

3. Selected tissue monitoring for heavy metal content is a potentially useful aspect of SUBASE Bangor environmental monitoring surveys.

4. Resident Hood Canal species such as oysters, mussels, crabs and rockfish have been seen to bioconcentrate certain heavy metals.

5. The establishment of a heavy metal baseline is important for continued monitoring of key elements of the marine ecosystem at SUBASE Bangor.

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APPENDIX A

SUBASE BANGOR SAMPLING STATIONS

	Station	Latitude (N)	Longitude (W)	Bearing (Magnetic)
		° ′ ″	° ′ ″	°
*Active Stations	A	47-42-51.5 47-42-51.0	122-44-50.0 122-44-53.0	250
	Z	47-43-28.0 47-43-29.0	122-44-36.0 122-44-37.0	305
	C	47-43-53.0 47-43-53.5	122-44-20.0 122-44-21.0	270
	D	47-44-14.5 47-44-19.0	122-44-04.0 122-44-06.5	322
	G	47-44-41.5 47-44-42.5	122-43-35.5 122-43-36.0	310
	J	47-46-16.0 47-46-20.0	122-42-17.5 122-42-26.0	290
**Inactive Stations	M	47-46-58.0 47-46-58.5	122-41-14.0 122-41-19.0	260
	L	47-46-30.0 47-46-33.0	122-42-03.0 122-42-04.5	310
	K	47-46-11.0 47-46-18.0	122-42-25.5 122-42-28.0	320
	FA	47-45-45.0 47-45-45.5	122-43-03.0 122-43-06.0	300
	E	47-44-15.0 47-44-22.0	122-43-55.5 122-44-01.0	315
	CS	47-43-47.0 47-43-49.0	122-44-36.0 122-44-36.0	340
	I	47-45-16.5 47-45-17.5	122-43-14.0 122-43-19.0	280

*As of June 1981.

**Station M was deleted after 1979; stations L, K & E were deleted after 1978; station FA & CS were deleted after 1977; station I was deleted after 1974.

Note: Intertidal sampling data were collected at the following stations during the years indicated: 1973–1981: A, C & G; 1973–1974: I; 1973–1978: E, K & L; 1975–1981: Z; 1977 only: CS & FA; 1979 only: M; 1979–1981: D & J.

Table A-1. SUBASE Bangor sampling stations: intertidal transects (first Lat/Long indicated position at extreme high tide mark for 12.0 feet; second Lat/Long indicates position at extreme low tide mark for -3.5 feet).

Station	Latitude (N)	Longitude (W)	Remarks
	° ' "	° ' "	
A	47-42-49.0	122-44-54.0	Midpoint*
	47-42-27.5	122-44-52.5	Southern limit
	47-43-03.0	122-44-55.0	Northern limit
Z	47-43-30.5	122-44-40.0	Midpoint
	47-43-17.5	122-44-49.5	Southern limit
	47-43-40.5	122-44-34.5	Northern limit
C	47-43-55.5	122-44-22.5	Midpoint
	47-43-49.5	122-44-32.0	Southern limit
	47-43-05.5	122-44-19.0	Northern limit
D-E	47-44-27.0	122-44-07.5	Midpoint
	47-44-12.5	122-44-22.5	Southern limit
	47-44-29.0	122-43-51.0	Northern limit
	47-45-35.0	122-43-11.0	Midpoint
	47-45-19.0	122-43-21.0	Southern limit
	47-45-51.5	122-43-04.0	Northern limit
J-K	47-46-22.5	122-42-24.5	Midpoint
	47-46-09.0	122-42-43.5	Southern limit
	47-46-32.0	122-42-09.0	Northern limit
M (L)	47-46-44.0	122-41-38.5	Midpoint
	47-46-35.0	122-41-07.0	Southern limit
	47-46-58.0	122-41-35.5	Northern limit

*denotes position midway between beginning and end of otter trawl haul.

Table A-2. SUBASE Bangor sampling stations: otter trawl hauls.

Station		Latitude (N)	Longitude (W)	Depth
		° ′ ″	° ′ ″	(meters)
A		47-42-49.0	122-44-54.0	10
NSP	(A)	47-43-50.5	122-44-29.5	10
	(B)	47-43-51.5	122-44-30.0	12
KB	(A)	47-44-06.0	122-44-18.5	8
	(B)	47-44-06.5	122-44-19.5	12
DC	(A1)	47-44-30.5	122-44-00.0	15
	(A2)	47-44-31.0	122-43-57.0	15
	(A3)	47-44-31.5	122-43-52.5	15
	(B1)	47-44-35.5	122-43-47.0	16
	(B2)	47-44-37.5	122-43-46.0	18
	(B3)	47-44-39.0	122-43-44.0	15
MW	(A1)	47-45-54.5	122-43-34.0	12
	(A2)	47-45-55.5	122-43-33.0	12
	(A3)	47-45-57.5	122-43-30.0	12
EHW		47-45-18.5	122-43-23.0	30

Table A-3. SUBASE Bangor sampling stations: sediments, heavy metals.

Station	Latitude (N)	Longitude (W)
	° ′ ″	° ′ ″
A	47-42-51.0	122-44-50.0
NSP	47-43-49.0	122-44-28.5
D-E	47-44-22.0	122-43-52.0
DC	47-44-34.5	122-43-44.0
MW(S)	47-44-43.5	122-43-34.5
MW(N)	47-44-55.5	122-43-28.5
EHW	47-45-18.0	122-43-17.0

Table A-4. SUBASE Bangor sampling stations: oysters, heavy metals.

Station	Latitude (N)	Longitude (W)
	° ′ ″	° ′ ″
A	47-42-49.0	122-44-53.0
NSP	47-43-50.0	122-44-29.5
KB	47-44-05.5	122-44-18.0
DC	47-44-34.5	122-43-44.0
MW(N)	47-44-55.5	122-43-28.5
EHW	47-45-18.5	122-43-19.5

Table A5. SUBASE Bangor sampling stations: mussels, heavy metals.

Station	Latitude (N)	Longitude (W)
	° ′ ″	° ′ ″
A	47-42-51.5	122-44-53.0
NSP	47-43-50.0	122-44-29.0
KB	47-44-06.0	122-44-19.0
D	47-44-19.0	122-44-06.5
G	47-44-42.5	122-43-36.0
EHW	47-45-18.5	122-43-19.5

Table A-6. SUBASE Bangor sampling stations: red rock crabs, heavy metals.

APPENDIX B

FISH TRAWL CATCH DATA

Species	Station A	C	D-E	I	J-K	M	Z	Total
Squalus acanthias	1							1
Hydrolagus colliei	1						1	2
Porichthys notatus								
Gadus macrocephalus								
Merluccius productus	8							8
Microgadus proximus				1	2			3
Aulorhynchus flavidus	2	+			+	3		5
Gasterosteus aculeatus					2			2
Syngnathus leptorhynchus	3	1	1		2			7
Cymatogaster aggregata	14	7	5	9	19	12	3	69
Embiotoca lateralis	21	4	1	3	3	7	1	40
Rhacochilus vacca				1				1
Anoplarchus purpurescens								
Lumpeneus sagitta					1			1
Apodichthys flavidus		1	1	2			1	5
Pholis laeta		1		1				2
Pholis ornata	7				1			8
Ammodytes hexapterus								
Coryphopterus nicholsi								
Sebastes caurinus	88	13	5	–	9		12	127
Hexagrammos stelleri			1					1
Artedius fenestralis								
Artedius lateralis								
Clinocottus acuticeps								
Enophrys bison								
Hemilepidotus hemilepidotus								
Leptocottus armatus	13	1	3		3	1	1	22
Nautichthys oculofasciatus								
Psychrolutes paradoxus						1		1
Scorpaenichthys marmoratus	1							1
Agonus acipenserinus								
Citharichthys sordidus								
Lepidopsetta bilineata						1		1
Parophrys vetulus	6	3	4		24	31		68
Platichthys stellatus	5	2						7
Pleuronichthys coenosus	1							1
Psettichthys melanostictus								
Total	171	33	21	17	66	56	19	383

Table B-1. Nighttime trawl data 8 July 1979 (0315-0540)
note: + = present; usually too numerous to count.

Species	Station A	C	D–E	I	J–K	M	Z	Total
Squalus acanthias						1		1
Hydrolagus colliei	1				2			3
Porichthys notatus	33				5			38
Gadus macrocephalus								
Merluccius productus	1				2			3
Microgadus proximus				4	17	15		36
Aulorhynchus flavidus			4	3	3		1	11
Gasterosteus aculeatus	+							–
Syngnathus leptorhynchus	37				1			38
Cymatogaster aggregata	15		4	3	12	14	3	51
Embiotoca lateralis	48		4	1				53
Rhacochilus vacca	1			2				3
Anoplarchus purpurescens								
Lumpeneus sagitta						5		5
Apodichthys flavidus	1							1
Pholis laeta	56						3	59
Pholis ornata					2			2
Ammodytes hexapterus								
Coryphopterus nicholsi	1			1				2
Sebastes caurinus	91	5	7	8	9		15	135
Hexagrammos stelleri	2			1				3
Artedius fenestralis	35	1	5		7	1	2	51
Artedius lateralis					1			1
Clinocottus acuticeps								
Enophrys bison	19						1	20
Hemilepidotus hemilepidotus				1				1
Leptocottus armatus	1	1		2	1	1		6
Nautichthys oculofasciatus	1			3	1	1		6
Psychrolutes paradoxus					+			–
Scorpaenichthys marmoratus	1						1	2
Agonus acipenserinus								
Citharichthys sordidus					1	1		2
Lepidopsetta bilineata				1	1			2
Parophrys vetulus	1				18	16		35
Platichthys stellatus	10							10
Pleuronichthys coenosus	8					2		10
Psettichthys melanostictus								
Total	363	7	24	30	85	55	26	590

Table B-2. Nighttime trawl series 13-14 July 1979 (2230-0145)
note: + = present; usually too numerous to count.

Species	Station A	C	D-E	I	J-K	M	Z	Total
Squalus acanthias								
Hydrolagus colliei								
Porichthys notatus								
Gadus macrocephalus								
Merluccius productus								
Microgadus proximus					1			1
Aulorhynchus flavidus			10	7	10	11		38
Gasterosteus aculeatus							1	1
Syngnathus leptorhynchus			4	1				5
Cymatogaster aggregata			50	6	5	22	9	92
Embiotoca lateralis			18	15		3		36
Rhacochilus vacca							1	1
Anoplarchus purpurescens								
Lumpeneus sagitta								
Apodichthys flavidus	1		2	2			3	8
Pholis laeta				1				1
Pholis ornata								
Ammodytes hexapterus								
Coryphopterus nicholsi								
Sebastes caurinus	1	7	2(3)	4(11)	(1)		7	36
Hexagrammos stelleri								
Artedius fenestralis			1					1
Artedius lateralis								
Clinocottus acuticeps								
Enophrys bison						1		1
Hemilepidotus hemilepidotus								
Leptocottus armatus				3				3
Nautichthys oculofasciatus								
Psychrolutes paradoxus								
Scorpaenichthys marmoratus								
Agonus acipenserinus								
Citharichthys sordidus								
Lepidopsetta bilineata								
Parophrys vetulus			2					2
Platichthys stellatus								
Pleuronichthys coenosus								
Psettichthys melanostictus								
Total	2	7	92	50	17	37	21	226

Note: ( ) = juveniles.

Table B-3. Daytime trawls 6 July 1979 (1410-1705).

Species	Station A	C	D-E	I	J-K	M	Z	Total
Squalus acanthias						1		1
Hydrolagus colliei					2			2
Porichthys notatus	1							1
Gadus macrocephalus								
Merluccius productus								
Microgadus proximus				1	4			5
Aulorhynchus flavidus	2			1		22		25
Gasterosteus aculeatus								
Syngnathus leptorhynchus								
Cymatogaster aggregata			1		1	2		4
Embiotoca lateralis								
Rhacochilus vacca	1							1
Anoplarchus purpurescens								
Lumpeneus sagitta					1	12		13
Apodichthys flavidus								
Pholis laeta	3							3
Pholis ornata			1				1	2
Ammodytes hexapterus								
Coryphopterus nicholsi								
Sebastes caurinus	28	4		9		(2)	14	57
Hexagrammos stelleri								
Artedius fenestralis								
Artedius lateralis				1		1		2
Clinocottus acuticeps						4		4
Enophrys bison	1							1
Hemilepidotus hemilepidotus								
Leptocottus armatus	2							2
Nautichthys oculofasciatus				1				1
Psychrolutes paradoxus			5	10		29		44
Scorpaenichthys marmoratus								
Agonus acipenserinus								
Citharichthys sordidus		2	3		7	3		15
Lepidopsetta bilineata					6	2	1	9
Parophrys vetulus	1	3	2	2	10	30		48
Platichthys stellatus						1		1
Pleuronichthys coenosus	2							2
Psettichthys melanostictus								
Total	41	9	12	25	31	109	16	243

Note: ( ) = juveniles.

Table B-4. Nighttime trawl series 24–25 June 1980 (2130–0115).

Species	Station A	C	D-E	I	J-K	M	Z	Total
Squalus acanthias					2			2
Hydrolagus colliei	2							2
Porichthys notatus	4				4			8
Gadus macrocephalus					1			1
Merluccius productus								
Microgadus proximus	1			2	8	2		13
Aulorhynchus flavidus	2		1		1	4		8
Gasterosteus aculeatus	1							1
Syngnathus leptorhynchus								
Cymatogaster aggregata	1			1	4	2		8
Embiotoca lateralis	3			2				5
Rhacochilus vacca								
Anoplarchus purpurescens		1						1
Lumpeneus sagitta					4	2		6
Apodichthys flavidus				1				1
Pholis laeta				1				1
Pholis ornata								
Ammodytes hexapterus								
Coryphopterus nicholsi								
Sebastes caurinus	20(1)	7(3)	5	13(1)	8		12	70
Hexagrammos stelleri								
Artedius fenestralis					13			13
Artedius lateralis	1				2	2		5
Clinocottus acuticeps								
Enophrys bison	1							1
Hemilepidotus hemilepidotus								
Leptocottus armatus								
Nautichthys oculofasciatus	1	1		4	2			8
Psychrolutes paradoxus				+	+			–
Scorpaenichthys marmoratus							1	1
Agonus acipenserinus					1			1
Citharichthys sordidus						20		20
Lepidopsetta bilineata	30				6	43	1	80
Parophrys vetulus	7			4	2	292	2	307
Platichthys stellatus								
Pleuronichthys coenosus	8			1	7			16
Psettichthys melanostictus						18		18
Total	83	12	6	30	65	385	16	597

Note: ( ) = juveniles

Table B-5. Nighttime trawl series 1-2 July 1980 (2330-0215)
note: + = present; usually too numerous to count.

Species	Station A	C	D-E	I	J-K	M	Z	Total
Squalus acanthias					1			1
Hydrolagus colliei			2			3		5
Porichthys notatus								
Gadus macrocephalus								
Merluccius productus								
Microgadus proximus					2			2
Aulorhynchus flavidus					1			1
Gasterosteus aculeatus								
Syngnathus leptorhynchus								
Cymatogaster aggregata		1				2		3
Embiotoca lateralis								
Rhacochilus vacca					1			1
Anoplarchus purpurescens	1							1
Lumpeneus sagitta								
Apodichthys flavidus								
Pholis laeta								
Pholis ornata								
Ammodytes hexapterus								
Coryphopterus nicholsi								
Sebastes caurinus	11		9		2			22
Hexagrammos stelleri								
Artedius fenestralis						1		1
Artedius lateralis								
Clinocottus acuticeps								
Enophrys bison								
Hemilepidotus hemilepidotus								
Leptocottus armatus					1			1
Nautichthys oculofasciatus								
Psychrolutes paradoxus								
Scorpaenichthys marmoratus	1							1
Agonus acipenserinus								
Citharichthys sordidus						3		3
Lepidopsetta bilineata	1	1				8		10
Parophrys vetulus		3				14	1	18
Platichthys stellatus								
Pleuronichthys coenosus					1			1
Psettichthys melanostictus								
Total	14	5	11	0	9	31	1	71

Table B-6. Nighttime trawls 28-29 May 1981 (2230-0130).

Species	Station A	C	D-E	I	J-K	M	Z	Total
Squalus acanthias								
Hydrolagus colliei								
Porichthys notatus								
Gadus macrocephalus								
Merluccius productus								
Microgadus proximus								
Aulorhynchus flavidus								
Gasterosteus aculeatus								
Syngnathus leptorhynchus				1				1
Cymatogaster aggregata		4		15				19
Embiotoca lateralis				8				8
Rhacochilus vacca								
Anoplarchus purpurescens								
Lumpeneus sagitta								
Apodichthys flavidus								
Pholis laeta								
Pholis ornata				2				2
Ammodytes hexapterus				1				1
Coryphopterus nicholsi								
Sebastes caurinus		4		4			4	12
Hexagrammos stelleri								
Artedius fenestralis				2				2
Artedius lateralis								
Clinocottus acuticeps								
Enophrys bison								
Hemilepidotus hemilepidotus								
Leptocottus armatus				1				1
Nautichthys oculofasciatus								
Psychrolutes paradoxus								
Scorpaenichthys marmoratus								
Agonus acipenserinus								
Citharichthys sordidus								
Lepidopsetta bilineata							1	1
Parophrys vetulus				1			1	2
Platichthys stellatus								
Pleuronichthys coenosus								
Psettichthys melanostictus								
Total		8		35			6	49

Table B-7. Nighttime trawls 5 June 1981 0330-0530 (stations Z, C and I only sampled).

APPENDIX C

OYSTER MANAGEMENT PLAN

NAVAL SUBMARINE BASE, BANGOR
FIVE YEAR MANAGEMENT PLAN FOR THE PACIFIC OYSTER, *Crassostrea gigas*
(FY82 to FY87)

I. INTRODUCTION

A. Objective:

The objective of this plan is to produce a managed oyster resource which will provide recreational opportunities to SUBASE personnel and dependents. It will also provide a means for commercial harvest of the excess resource which is surplus to the needs of recreational activity.

B. Background:

Between June 18 and July 2, 1981 beaches containing the Pacific oyster, *Crassostrea gigas*, along SUBASE, Bangor were surveyed for quantity and density of oysters (figure C-1). This information, along with a proposed management plan for the resource was presented to the Commanding Officer SUBASE on 27 August 1981. This meeting resulted in the management plan presented below.

II. SURVEY METHODS

Beaches with obvious oyster beds were chosen for survey. The beds were measured for length and every 30 meters a bed width was recorded. At every width site samples were taken at top, middle and bottom by a random toss of 0.1 M^2 (1 ft^2) ring. Oysters within the ring were sorted into those greater than 3 inches in length and those 3 inches or less in length, and counted. (The 3 inch criteria was chosen because it represents commercial desirability and SUBASE requires a 3 inch minimum length for recreational harvest.) The area, average density, and number of oysters in each bed were then calculated.

III. SURVEY RESULTS

Table C-1 summarizes the survey results by beach. Beach numbers refer to oyster beds indicated in figure C-1. Beaches 3 and 4 contain large numbers of commercial size oysters. Oyster densities on commercial beds are generally regulated to yield 1,000 to 1,500 bushels per acre. Beaches 3 and 4 contain 9,900 and 13,500 bushels per acre respectively of commercial size oysters. One bushel of adult sized oysters contain 80 to 125 oysters and will yield about 8 pints of shucked meats.

IV. MANAGEMENT PLAN

Table C-2 is a summary of the Five Year Oyster Resource Management Plan.

Beach Number (Beach Name)	Area in Acres	Average Density (ft^2)	Total Number Oysters	Number Oysters Less than 3" in Length	Number Oysters 3" and Greater in Length	Number Limits (3" and Larger)
1. Cattail Beach						
(a)	0.27	13.3	158,000	34,000	124,000	6,900
(b)	0.17	13.1	95,000	20,000	75,000	4,200
(c)	0.04	8.5	14,000	3,000	11,000	600
(d)	0.46	19.2	385,000	96,000	289,000	16,000
2. Tang Beach						
(a)	1.8	12.3	962,000	297,000	665,000	37,000
(b)	0.13	7	40,000	17,000	23,000	1,300
3. Carlson Cove	1.8	34	2,559,000	602,000	1,957,000	109,000
4. Carlson-South	2.4	42	4,428,000	1,223,000	3,205,000	178,000
5. Devils Delta & EHW Beach						
(a)	0.7	9.4	270,000	69,000	201,000	11,000
(b)	0.09	14.3	58,000	24,000	34,000	1,900
(c)	0.13	21	118,000	14,000	104,000	5,800
(d)	0.07	46	138,000	27,000	111,000	6,200
(e)	0.14	13	79,000	18,000	61,000	3,400
(f)	0.3	17.8	234,000	42,000	192,000	10,700
(g)	0.11	42.4	202,000	32,000	170,000	9,400
(h)	0.18	14	110,000	25,000	85,000	4,700
TOTALS	8.79		9,850,000	2,543,000	7,307,000	406,100

Table C-1. Summary of 1981 oyster survey: Naval Submarine Base Bangor.

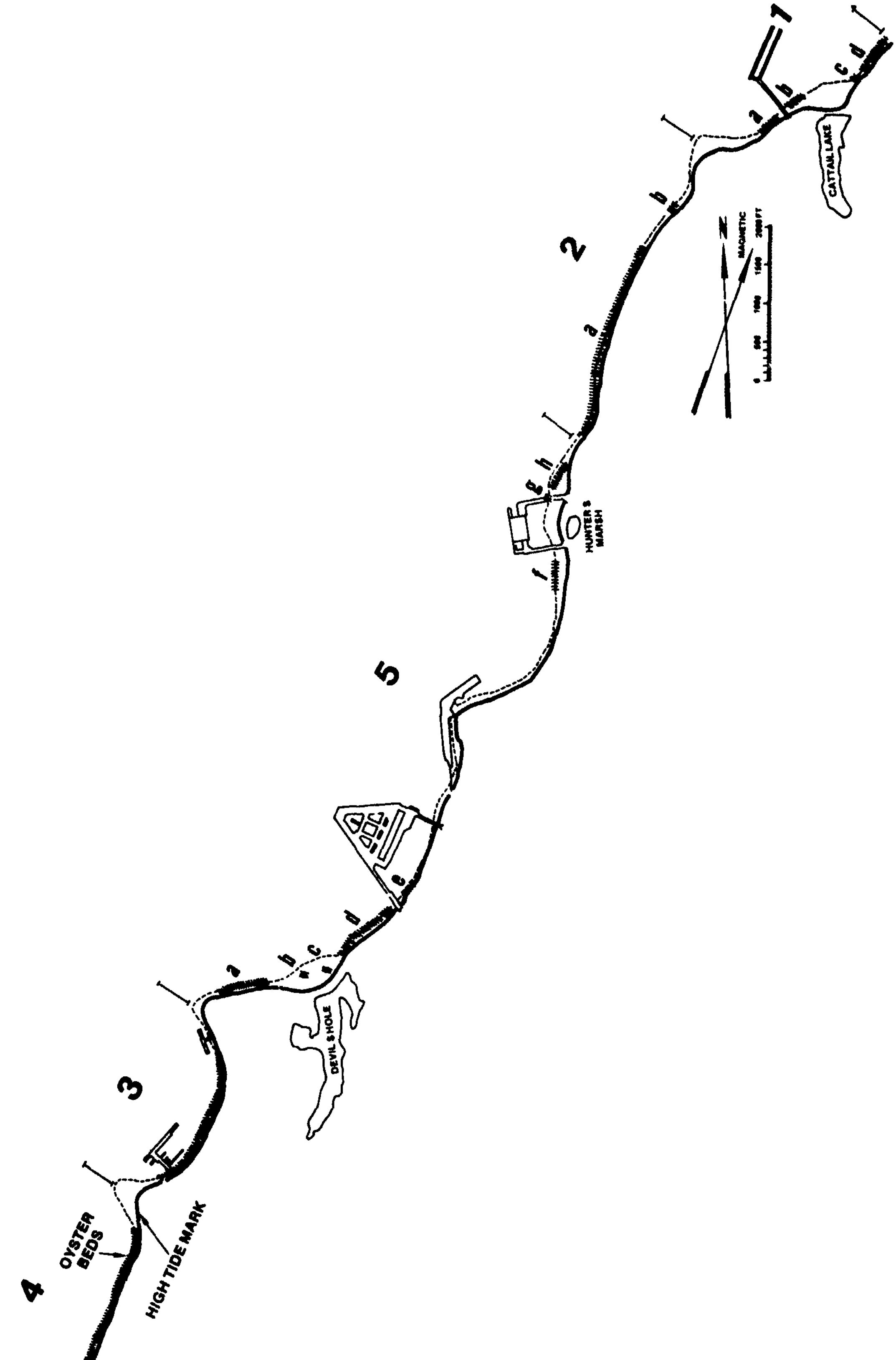


Figure C-1. Oyster bed locations along SUBASE Bangor during 1981 survey.

A. Recreational Shell Fishing

The management plan was developed to provide adequate recreational harvest for SUBASE personnel with a projected annual harvest of 20,000 limits at 18 oysters per limit per year. The projected limits are higher than records indicate for past years, and perhaps will not be attained in the initial years of this plan. This management plan will be amended each year to reflect actual recreational harvest experience. Harvest rates are expected to increase with the increase in Base population in the next several years.

Beaches will be utilized, in most cases, for both clam and oyster sport fishing and in some cases, such as Beaches 3 and 4 where dense concentration of oysters exist, only a limited area of beach should be opened at any one time during the recreational harvest period. Strip harvesting is recommended on these beaches because clam diggers may trample the oyster beds in search of clams. Opening small sections of the beach to oyster and clam harvest will eliminate much of the wastage that could occur if the entire beach were accessible.

B. Commercial Harvest

Beaches 4 and 5 will be opened to commercial permit harvest during FY 82. Beach 4 contains the highest density of oysters and is extremely overcrowded. Beach 5 is planned for harvesting in FY82 because of anticipated tightened security in future years. Beach 3 will be opened for commercial fishing in FY83, in order to harvest an estimated 2.3 million oysters remaining after the recreation take in FY82. No additional commercial harvesting is anticipated until FY86, and would take place at Beach 4 after the recreational harvest of FY85 (table C-2). Commercial harvesting will take place during winter or early spring, depending upon oyster condition, marketing and the permittees' schedule.

C. Reseeding

A portion of the monies generated from the commercial harvest will be used to reseed beaches that have been harvested or contain small populations of oysters. Reseeding will only be done at Beaches 1, 2, 3, and 4 as it is expected that tightened security at Beach 5 will preclude recreational or commercial use of this area. Seeding will take place in April or May of each year in order to take advantage of the spring and summer period of optimum growth conditions. Reseeded beaches will be opened for harvesting at two and one half year intervals, depending upon growth rate.

D. Management Plan Revision

Shellfish populations are dynamic and subject to changes such as growth, harvest, and depredation. Management priorities and security requirements are also dynamic. The harvest schedule presented in table C-2 will be revised at the intervals necessary to reflect changes in populations or priorities, and to reflect the success of new programs such as oyster seeding and commercial harvest.

FY 1982 — Action Item	O	N	D	J	F	M	A	M	J	J	A	S
1. Open Beach 3 for recreational fishing	R	R	R	R	R	R	R	R	R	R		
2. Prepare and award commercial harvest permit	X	X	X	X								
3. Commercial harvest Beaches 4 and 5				C	C	C	C	C				
4. Reseed Beach 4							S	S				
5. Open Beach 2 for recreational fishing												R
6. Prepare and award commercial harvest permit												
7. Commercial harvest Beach 3												
8. Reseed Beach 3												
9. Open Beach 1 for recreational fishing												
10 Reseed Beach 2												
11. Open Beach 4 for recreational shellfishing												
12. Reseed Beach 1												

FY 1983 — Action Item	O	N	D	J	F	M	A	M	J	J	A	S
1. Open Beach 3 for recreational fishing												
2. Prepare and award commercial harvest permit												
3. Commercial harvest Beaches 4 and 5												
4. Reseed Beach 4												
5. Open Beach 2 for recreational fishing	R	R	R	R	R	R	R	R	R	R		
6. Prepare and award commercial harvest permit	X	X										
7. Commercial harvest Beach 3				C	C	C						
8. Reseed Beach 3							S	S				
9. Open Beach 1 for recreational fishing												R
10 Reseed Beach 2												
11. Open Beach 4 for recreational shellfishing												
12. Reseed Beach 1												

FY 1984 — Action Item	O	N	D	J	F	M	A	M	J	J	A	S
1. Open Beach 3 for recreational fishing												
2. Prepare and award commercial harvest permit												
3. Commercial harvest Beaches 4 and 5												
4. Reseed Beach 4												
5. Open Beach 2 for recreational fishing												
6. Prepare and award commercial harvest permit												
7. Commercial harvest Beach 3												
8. Reseed Beach 3												
9. Open Beach 1 for recreational fishing	R	R	R	R	R	R	R	R	R	R		
10 Reseed Beach 2							S	S				
11. Open Beach 4 for recreational shellfishing												R
12. Reseed Beach 1												

FY 1985 — Action Item	O	N	D	J	F	M	A	M	J	J	A	S
1. Open Beach 3 for recreational fishing												R
2. Prepare and award commercial harvest permit												
3. Commercial harvest Beaches 4 and 5												
4. Reseed Beach 4												
5. Open Beach 2 for recreational fishing												
6. Prepare and award commercial harvest permit												
7. Commercial harvest Beach 3												
8. Reseed Beach 3												
9. Open Beach 1 for recreational fishing												
10 Reseed Beach 2												
11. Open Beach 4 for recreational shellfishing	R	R	R	R	R	R	R	R	R	R		
12. Reseed Beach 1							S	S				

FY 1986 — Action Item	O	N	D	J	F	M	A	M	J	J	A	S
1. Open Beach 3 for recreational fishing	R	R	R	R	R	R	R	R	R	R		
2. Prepare and award commercial harvest permit	X	X										
3. Commercial harvest Beaches 4 and 5				C (Beach 4)	C	C						
4. Reseed Beach 4							S	S				
5. Open Beach 2 for recreational fishing												
6. Prepare and award commercial harvest permit												
7. Commercial harvest Beach 3												
8. Reseed Beach 3												
9. Open Beach 1 for recreational fishing												
10 Reseed Beach 2												
11. Open Beach 4 for recreational shellfishing												
12. Reseed Beach 1												

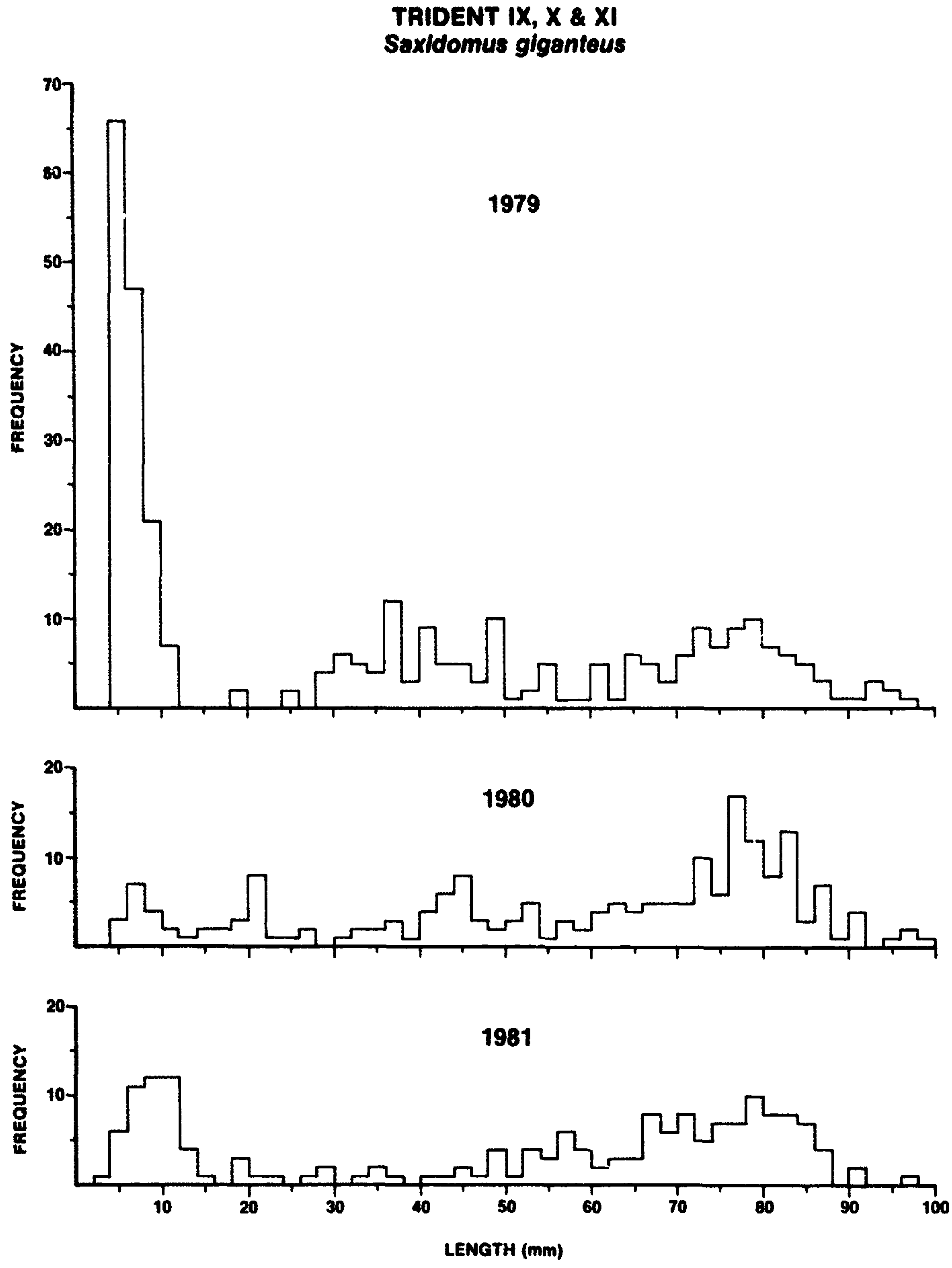
Note Washington State Regulations prohibit recreational oyster harvest between July 15 and September 15

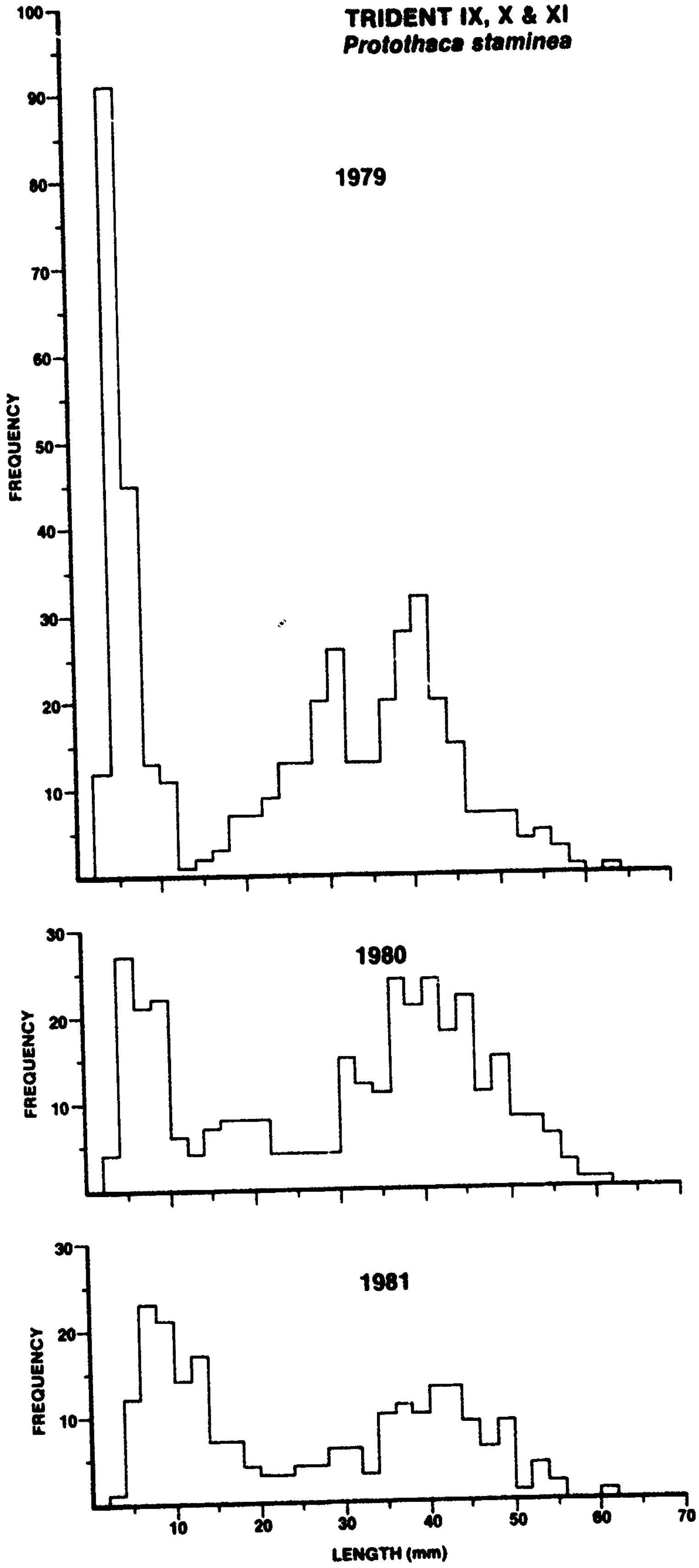
Table C-2. Five-year oyster resource management plan.

APPENDIX D

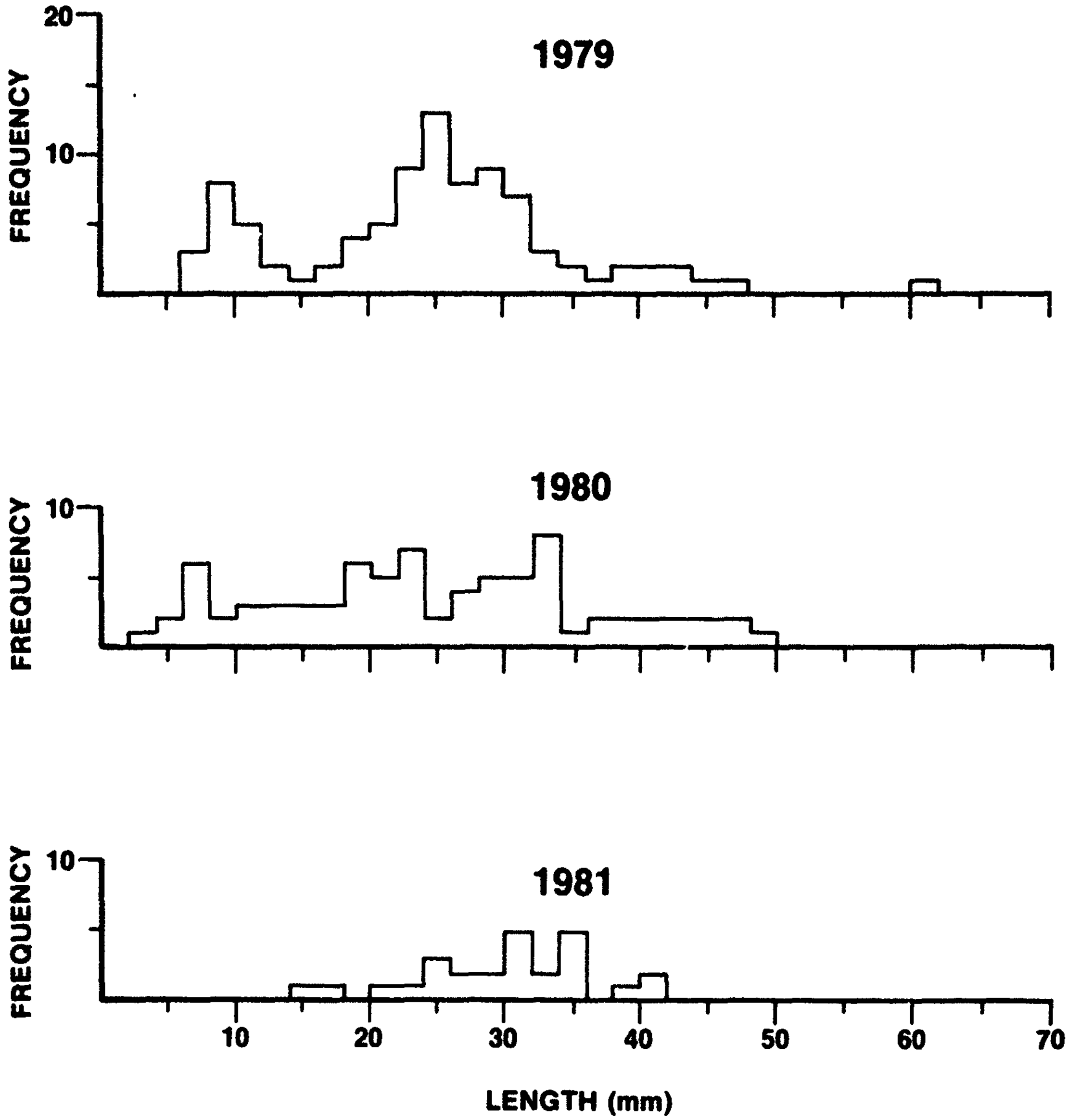
BIVALVE MOLLUSC LENGTH-FREQUENCY DISTRIBUTIONS

Bivalve length-frequency distribution data collected at SUBASE Bangor during 1979, 1980 and 1981 surveys are presented in figures D-1 through D-4 for *Saxidomus giganteus, Protothaca staminea, Tapes japonica* and *Clinocardium nuttallii*, respectively.


TRIDENT IX, X & XI
Saxidomus giganteus
1979
1980
1981
FREQUENCY
70
60
50
40
30
20
10
10
20
10
20
10
20
30
40
50
60
70
80
90
100
LENGTH (mm)


TRIDENT IX, X & XI
Protothaca staminea
1979
1980
1981
FREQUENCY
LENGTH (mm)
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70

TRIDENT IX, X & XI
Tapes japonica



APPENDIX E

SELECTED IMPORTANT SPECIES

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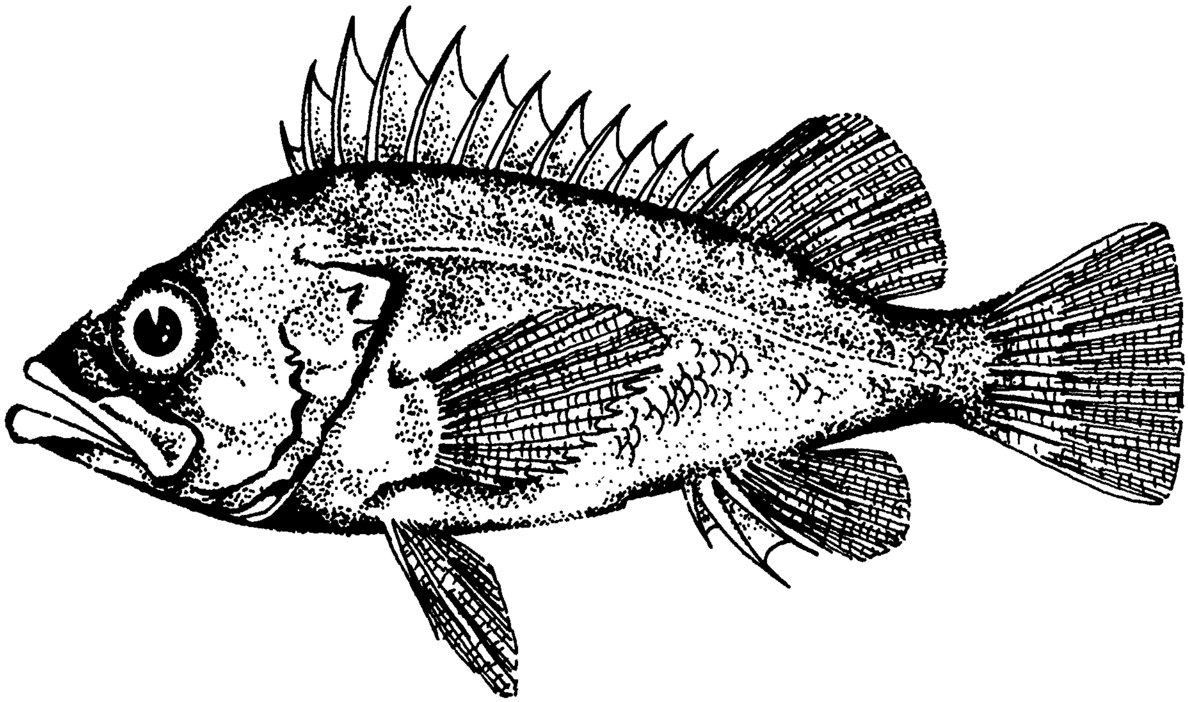
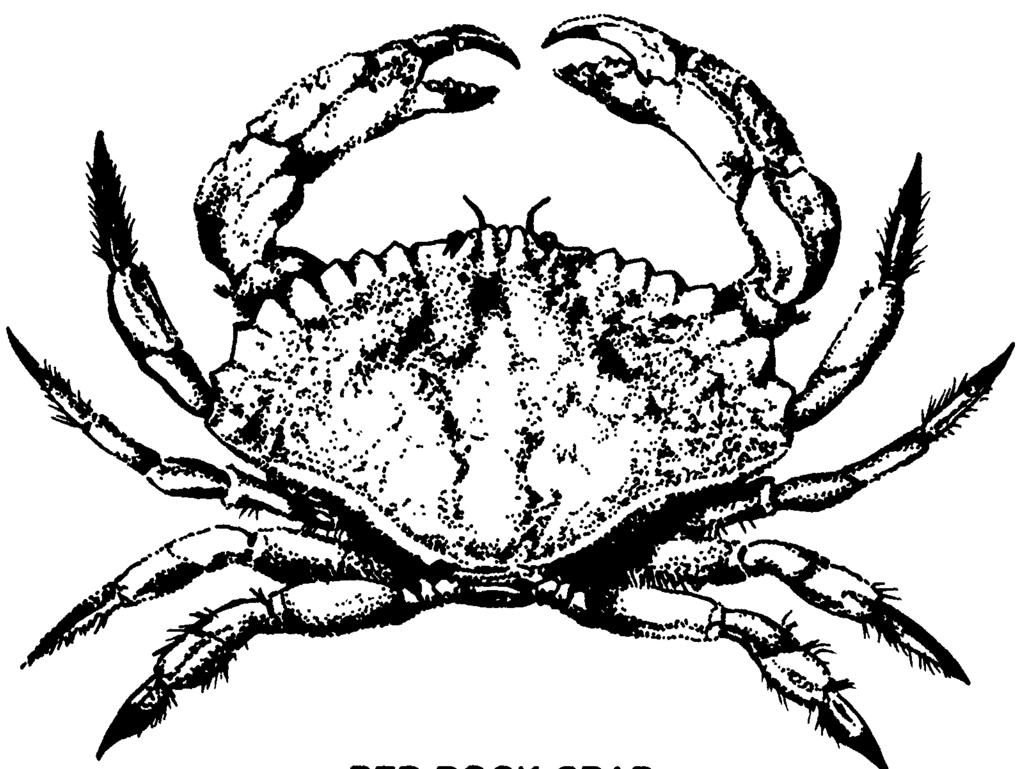
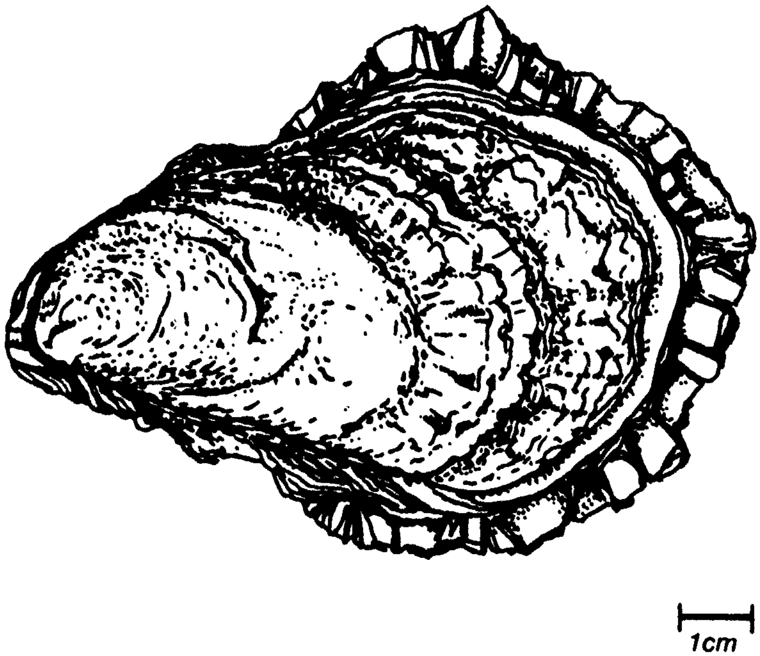


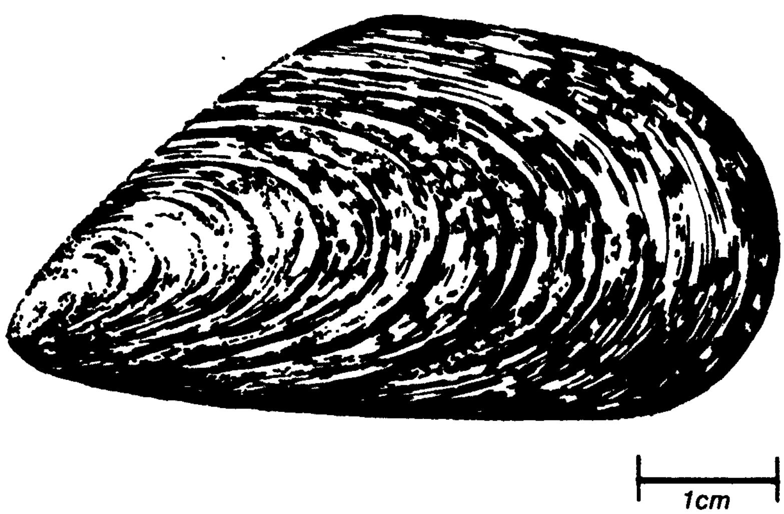
COPPER ROCKFISH
Sebastes caurinus Richardson, 1845



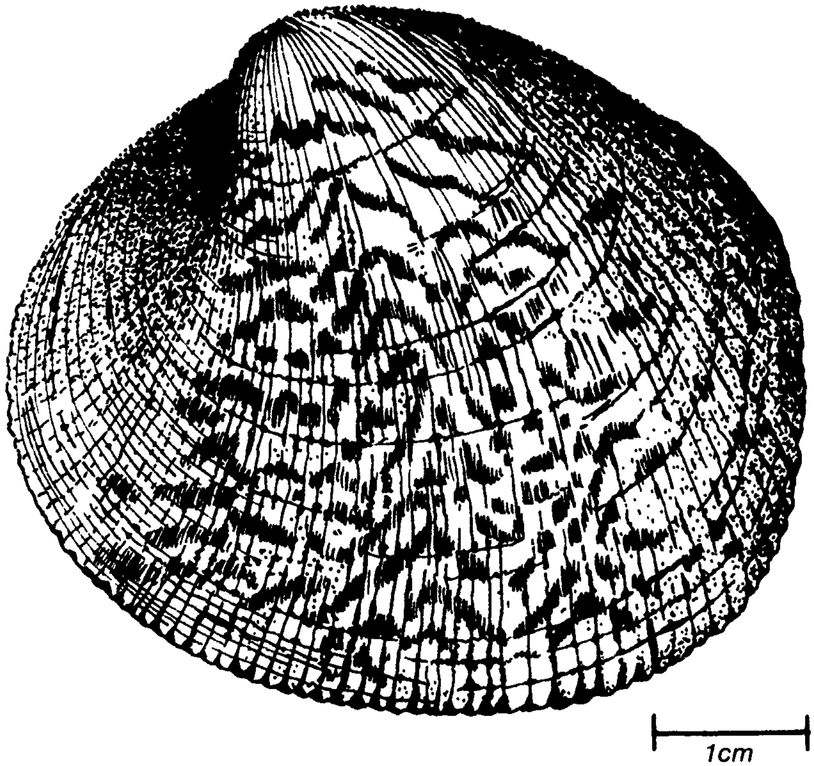
RED ROCK CRAB
Cancer productus Randall, 1839



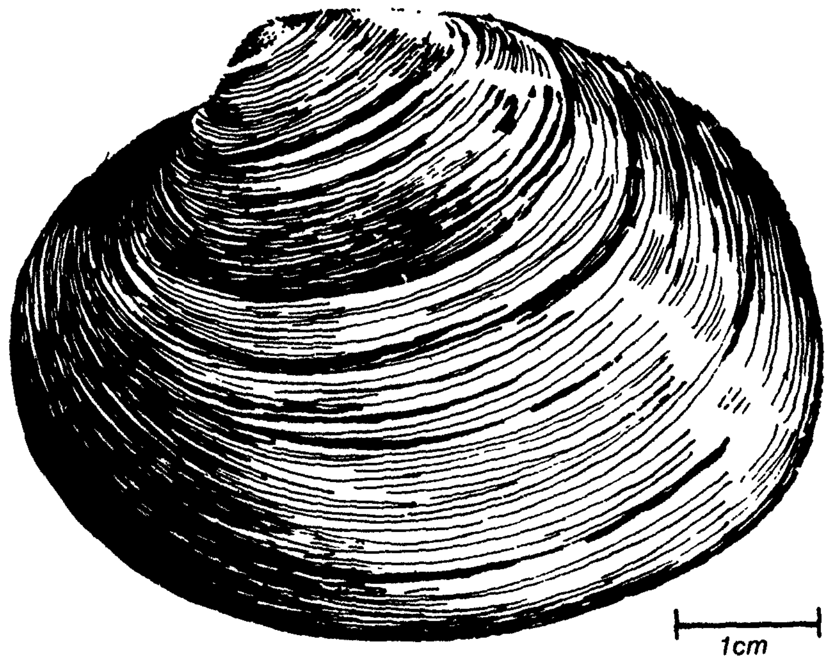
GIANT PACIFIC OYSTER
Crassostrea gigas (Thunberg, 1795)



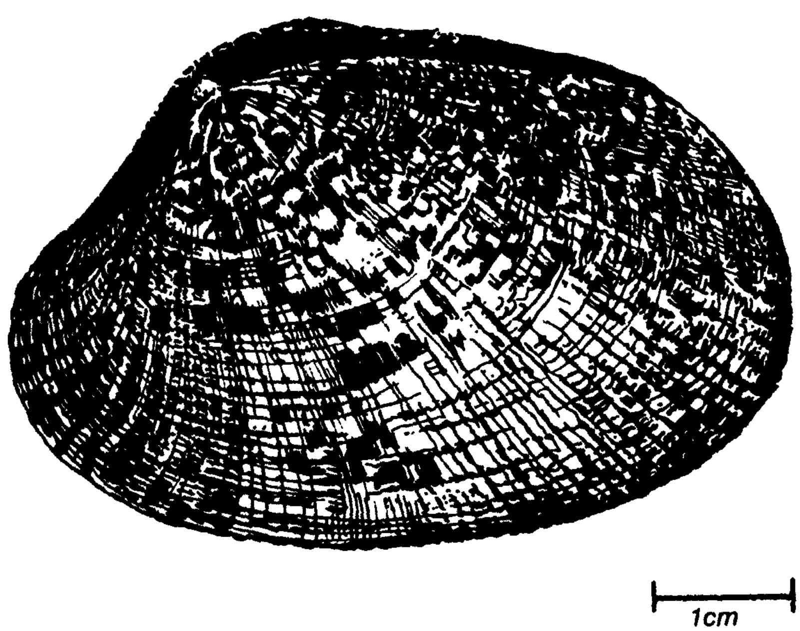
BAY MUSSEL
Mytilus edulis Linnaeus, 1758



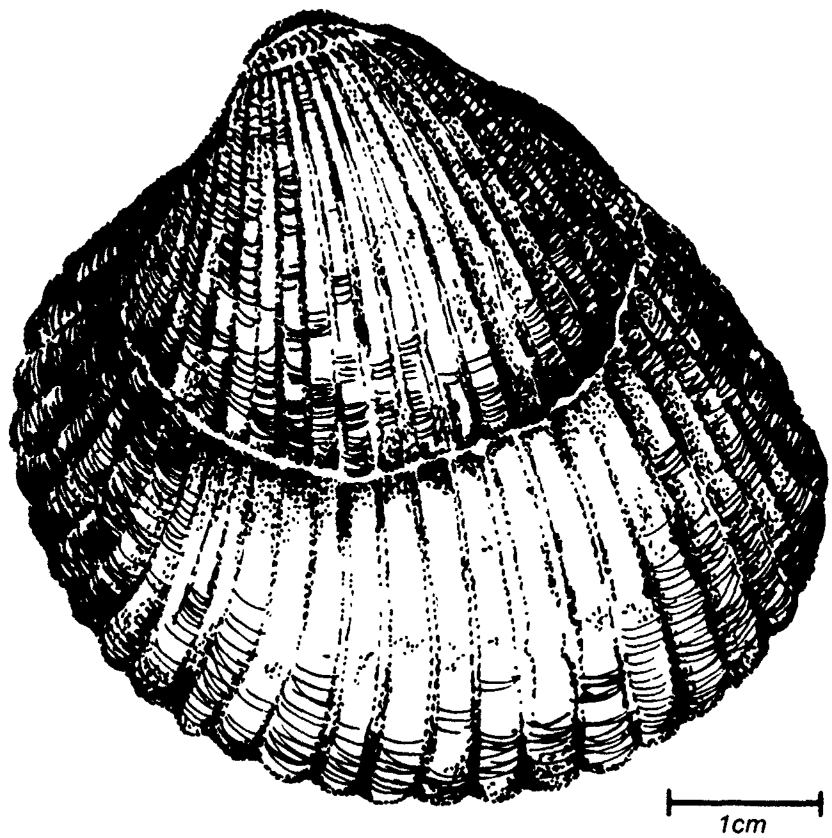
NATIVE LITTLENECK
Protothaca staminea (Conrad, 1837)



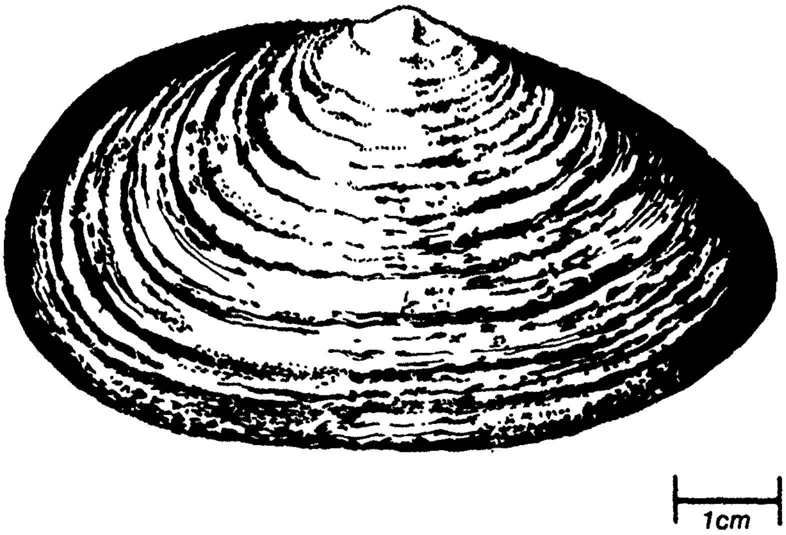
BUTTER CLAM
Saxidomus giganteus (Deshayes, 1839)



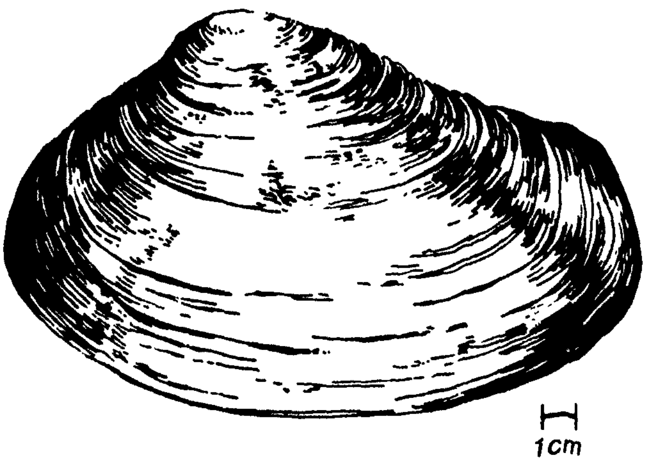
MANILA LITTLENECK
Tapes japonica Deshayes, 1853



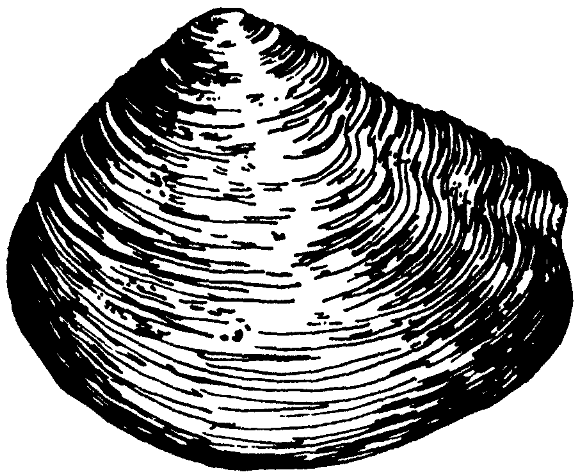
BASKET COCKLE
Clinocardium nuttallii (Conrad, 1837)



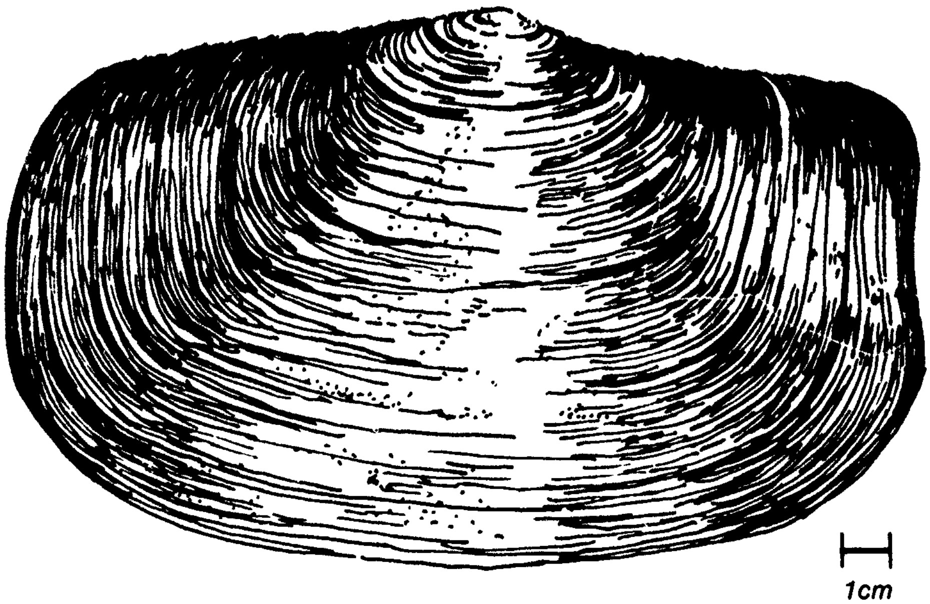
EASTERN SOFTSHELL
Mya arenaria Linnaeus, 1758



HORSE CLAM
Tresus nuttallii (Conrad, 1837)



HORSE CLAM
Tresus capax (Gould, 1850)



GEODUCK
Panopea generosa (Gould, 1850)

The Copper rockfish is a common species which inhabits both eelgrass-laminarian-sargassum and piling habitats along SUBASE Bangor. Its geographic range extends from Monterey Bay, California to the Gulf of Alaska. The copper rockfish possesses dark fins, a dark brown to olive coloration on the upper body, blotched coppery coloration laterally, and a deep caudal peduncle. This species bears its young alive, usually during June and July adjacent to SUBASE Bangor. Primary food items for this species include shrimp, fishes, worms and miscellaneous other crustaceans such as amphipods, crabs and isopods. Copper rockfish are prized for human consumption in Puget Sound and have been observed to weigh up to 5 kg in Hood Canal. This species has been used for heavy metal monitoring (muscle and liver tissue) and extensive food habit observations during SUBASE Bangor environmental investigations.

The red rock crab is common subtidally along SUBASE Bangor waterfront areas, especially adjacent to piers and pilings. Its geographic distribution extends from Magdelena Bay, Baja California to Kodiak Island. The red rock crab can be recognized from the dungeness crab by its dark red upper carapace surface and yellowish underside with red-orange blotches. The tips of the large claws are black-tipped. Red rock crabs have an extended breeding season in Hood Canal from spring through late summer. While less desirable for human consumption than the dungeness crab, red rock crabs are often collected intertidally along SUBASE Bangor by sports clam harvesters. This species is being used for heavy metal monitoring during ongoing environmental studies at SUBASE Bangor.

The Pacific (or Japanese) oyster population inhabiting the SUBASE Bangor waterfront areas presently consists of extensive intertidal beds along most open beaches (see appendix C). An excellent oyster spatfall occurred during several recent years (1978-1980) throughout northern Hood Canal waters. This species occurs from Morro Bay, California to British Columbia. The pacific oyster was introduced from Japan during the 1920-1930 period. A commercial oyster industry exists in several regions of Puget Sound. Oysters in Hood Canal usually spawn during July and August when water temperatures are favorably warm (usually about 67 degrees Farenheit). For normal growth of oyster larvae during the first several weeks of existence, water temperatures above 68 degrees F are required. Adult pacific oysters will reach lengths in excess of 30 cm. This species also is being used for heavy metal monitoring at SUBASE Bangor during environmental studies.

The bay mussel (or blue mussel) inhabits pilings and floating structures along SUBASE Bangor waterfront areas. This cosmopolitan species is distributed worldwide in sheltered bays and estuaries. Bay mussels form dense aggregations on pilings and are important members of the food web in Hood Canal. While cultured in Europe and on the east coast for human consumption, this species has only recently been utilized on the Pacific Coast for other than fishing bait. Spawning occurs in spring and early summer in Puget Sound. This species has been used for heavy metal monitoring at SUBASE Bangor. An extensive amount of literature exists for this species as a test organism for environmental monitoring studies.

The native littleneck (or steamer) clam is abundant intertidally along SUBASE Bangor beaches. This species occurs from lower California to the Aleutian Islands. Spawning occurs in late spring and early summer in Hood Canal. Native littleneck clams occur higher intertidally than butter clams and shallower (about 3-5 cm deep) in the substratum. This species is densest in cobble beach habitats. Native litttleneck clams are usually more round in shape and white in coloration than the Manila or Japanese littleneck clam. This species is highly esteemed for human consumption in Puget Sound and elsewhere. Native littleneck clams were the most numerically dominant clam species during SUBASE Bangor environmental investigations.

The Manila (or Japanese) littleneck clam is abundant on some beaches along SUBASE Bangor. This species is usually more elongate than the native littleneck clam. The Manila littleneck clam often has intricate geometric patterns on the shell. Its geographic distribution ranges from Elkhorn Slough, California to British Columbia. This species was introduced with Japanese seed oysters during the 1920-1930 period. Spawning of Manila littleneck clams occurs from May-October, with a peak in July for Hood Canal waters. This species is often collected along with native littleneck clams for "steaming" and is an excellent food clam in Puget Sound.

The butter clam is abundant along SUBASE Bangor intertidal regions. Its geographic range occurs from northern California to the Aleutian Islands. This species is the most important commercial clam species in Puget Sound. Butter clams attain a relatively large adult size (commonly 80-100 mm in length). Butter clams are excellent for human consumption, usually being fried or used for chowder. This species spawns in Hood Canal during April to October. Juvenile butter clams and siphon tips of adults are important diet items for many Hood Canal fishes. This species represented the greatest biomass of bivalves sampled during SUBASE Bangor environmental studies. This species will be used for heavy metal monitoring beginning with the 1982 survey.

Basket cockles are common along some SUBASE Bangor beaches, usually inhabiting the gently sloping, delta regions in the sand and eelgrass habitat. Its geographic distribution ranges from San Diego, California to the Bering Sea. Spawning usually occurs during midsummer (July-August) in Hood Canal for this hermaphroditic bivalve species. Basket cockles are tasty, excellent food clams; however, adults of this species are quite tough when cooked unless thay are chopped or ground into chowder. Juveniles of this species are a major food source for many Hood Canal fish species.

Eastern soft-shell clams are sometimes collected along SUBASE Bangor shorelines. This species was accidentally introduced on the Pacific Coast about 1870 in shipments of eastern oysters to California and Washington. Later, eastern soft-shell clams were planted in several areas from California to Alaska. Its present geographic range extends from Elkhorn Slough, California to British Columbia. This species prefers muddy habitats with freshwater influences. Spawning occurs in midsummer for this species. Eastern soft-shell clams are a good food species; however, they require purging in fresh seawater for several days to remove gritty sediment from their digestive system.

Horse (or gaper) clams are common at several beaches along SUBASE Bangor waterfront areas. These two species occur from San Diego, California to Alaska. Horse clams occur subtidally and are only visible intertidally during low tides (below zero tidal levels, usually) in Hood Canal. These species spawn in late winter and spring. *Tresus capax* is a host for commensal crabs (usually a male and female crab are present under the visceral skirt) and is the rounder of these two species. It also occurs shallower in the substratum, usually about 20-30 cm deep. Horse clams are less frequently sought for human consumption than other hard-shell clam species.

The geoduck clam represents the largest bivalve in the Puget Sound region, often attaining a weight of 6-7 kg. This species is abundant subtidally along SUBASE Bangor in Hood Canal and spawns in spring and early summer, with a peak usually occurring in June in Hood Canal. Geoduck clams are harvested commercially by divers in Puget Sound for shipment to many distant areas, such as Hawaii. Earlier SUBASE Bangor environmental surveys documented populations of geoduck and horseneck clams by diver surveys along preestablished transect lines. Divers recorded siphon tips or depressions and found the densest populations of geoduck clams off Cattail Delta at about 15-25 metres water depth. This species occurs nearly a metre deep in the substratum.

APPENDIX F

TAXONOMIC CHECKLIST ADDITIONS

Additions to the SUBASE Bangor cumulative checklist of organisms collected from Hood Canal are listed in table F-1. Reference specimens of these taxa are maintained at the NOSC sample processing center located at the Hawaii Laboratory.

TAXA

CNIDARIA

Hydrozoa

Obelia plicata Hincks, 1868
Clytia edwardsi (Nutting, 1901)
Euphysa flammea (Lincko, 1905)

Anthozoa

Anthopleura artemisia (Pickering in Dana, 1948)

NEMERTEA

Carinoma mutabilis Griffin, 1898

ENTOPROCTA

Barentsia ramosa (Robertson, 1900)

ECTOPROCTA

Schizoporella unicornis (Johnson, 1847)

ANNELIDA

Pectinaria granulata (Linnaeus, 1767)

ARTHROPODA

Isopoda

Gnorimosphaeroma oregonensis (Dana, 1854)

Caprellidea

Metacaprella anomala (Mayer, 1903)

Gammaridea

Pontogenia intermedia Gurjanova, 1938

Decapoda

Pagurus hirsutiusculus (Dana, 1851)
Pinnixia occidentalis Rathbun, 1893
Pinnixia tubicola Holmes, 1895

ECHINODERMATA

Amphodia occidentalis (Lyman, 1860)

CHORDATA

Batrachoididae

Porichthys notatus Girard, 1854

Gadidae

Gadus macrocephalus Tilesius, 1810

Cottidae

Artedius lateralis (Girard, 1854)

Agonidae

Agonus acipenserinus Tilesius, 1811

Bothidae

Citharichthys sordidus (Girard, 1854)

Table F-1. Additions to the SUBASE Bangor cumulative checklist.